NASA X-15 PROGRAM

By: T.D. Barnes - NASA Contractor - 1960s

NASA contractors for the X-15 program were Bendix Field Engineering followed by Unitec, Inc. The NASA High Range Tracking stations were located at Ely and Beatty Nevada with main control being at Dryden/Edwards AFB in California. Personnel at the tracking stations consisted of a Station Manager, a Technical Advisor, and field engineers for the Mod-2 Radar, Data Transmission System, Communications, Telemetry, and Plant Maintenance/Generators. NASA had a site monitor at each tracking station to monitor our contractor operations.

Though supporting flights of the X-15 was their main objective, they also participated in flights of the XB-70, the three Lifting Bodies, experimental Lunar Landing vehicles, and an occasional A-12/YF-12/SR-71 Blackbird flight.

On mission days a NASA van picked up each member of the crew at their residence for the 4:20 a.m. trip to the tracking station 18 miles North of Beatty on the Tonopah Highway. Upon arrival each performed preflight calibrations and setup of their various systems. The liftoff of the B-52, with the X-15 tucked beneath its wing, seldom occurred after 9:00 a.m. due to the heat effect of the Mojave Desert making it difficult for the planes to acquire altitude.

At approximately 0800 hours two pilots from Dryden would proceed uprange to evaluate the condition of the dry lake beds in the event of an emergency landing of the X-15 (always buzzing our station on the way up and back). The most popular of these launch lakes were Mud, Delamar, Hidden Hills, Smith Ranch, Silver, Railroad Valley, Rosamond, and Cuddeback.

EMERGENCY LANDING SITES

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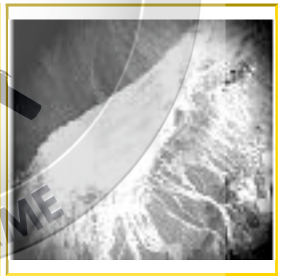








Each mission commenced with B-52 Zero-Zero-Eight and the chase planes (F-104s and an occasionally NASA'S T-33) lifting off at Rogers dry lake and circling Edwards AFB as they ascended to the 45,000 feet altitude required for the launch. The B-52 usually reached altitude as it flew over Baker, California, during which time the X-15 pilot was performing preflight checks of the X-15, testing various communications channels, etc. The airways were quite busy.

As the aerial entourage proceeded up range, Beatty radar and telemetry would acquire track along with its counterparts at Dryden, giving NASA the option of using the track of whichever radar it desired. When the planes proceeded beyond the range of NASA/Dryden radar, Beatty radar would provide the tracking functions. Meanwhile, Ely radar and telemetry would be trying to acquire tracking for when the flight tracking passed from Beatty to Ely tracking station. (All three tracking stations kept their radar and telemetry system slaved to the one with the most solid track until they acquired their own tracking capabilities) If everything was go for the mission, the X-15 would launch and 7 minutes later be landing at Dryden, an hour or more ahead of the mothership
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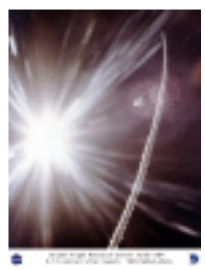
X-15 Movie Clip

PILOTS AND PLANES

The X-15 #2 (56-6671) launches away from the B-52 mothership with its rocket engine ignited. The white patches near the middle of the ship are frost from the liquid oxygen used in the propulsion system, although very cold liquid nitrogen was also used to cool the payload bay, cockpit, windshields, and nose.

The X-15 rocket-powered aircraft begins its climb after launch at the NASA Flight Research Center, Edwards, California (later renamed the Dryden Flight Research Center).



The North American X-15 settles to the lakebed after a research flight from what is now the NASA Dryden Flight Research Center, Edwards, California.

Followed by a Lockheed F-104A Starfighter chase plane, the North American X-15 ship #3 (56-6672) sinks toward touchdown on Rogers Dry Lake following a

research flight.

This photo shows the X-15A-2 (56-6671) on a research flight with a dummy ramjet engine attached to the bottom of its wedge-shaped vertical tail.

As crew members secure the X-15 rocket-powered aircraft after a research flight, the B-52 mothership used for launching this unique aircraft does a low fly-by overhead. The X-15s made a total of 199 flights over a period of nearly 10 years -- 1959 to 1968 -- and set unofficial world speed and altitude records of 4,520 mph (Mach 6.7) and 354,200. According to an early edition of 'the Guinness book of world records' the X15 also holds the record for fastest landing speed at 242 mph compared with 210 mph for the space shuttle. Information gained from the highly successful X-15 program contributed to the development of the Mercury, Gemini, and Apollo piloted spaceflight programs, and also the Space Shuttle program.

This photo shows the X-15-1 (56-6670) rocket powered research aircraft as it was rolled out in 1958. At this time, the XLR-99 rocket engine was not ready, so to make the low-speed flights (below Mach 3), the X-15 team fitted a pair of XLR-11 engines into the modified rear fuselage. These were basically the same engines used in the X-1 aircraft.

In June 1967, the X-15A-2 rocket-powered research aircraft received a full-scale ablative coating to protect the craft from the high temperatures associated with hypersonic flight (above Mach 5). This pink eraser-like substance, applied to the X-15A-2 aircraft (56-6671), was then covered with a white sealant coat before flight. This coating would help the #2 aircraft reach the record speed of 4,520 mph (Mach 6.7).

In June 1967, the X-15A-2 rocket powered research aircraft received a full-scale ablative coating to protect the craft from the high temperatures associated with supersonic flight. This pink eraser-like substance, applied to the #2 aircraft (56-6671), was then covered with a white sealant coat before flight. This coating would help the #2 aircraft reach the record speed of 4,520 mph (Mach 6.7).

After receiving a full-scale ablative coating to protect the craft from the high temperatures associated with supersonic flight, the X-15A-2 rocket-powered research aircraft was then covered with a white sealant coat. This ablative coating and sealant would help the #2 aircraft reach the record speed of 4,520 mph (Mach 6.7).

After receiving a full scale ablative coating to protect the craft from the high temperatures associated with high-Mach-number supersonic flight, the X-15A-2 (56-6671) rocket powered research aircraft was then covered with a white sealant coat and mounted with additional external fuel tanks. This ablative coating and sealant would help the #2 aircraft reach the record speed of 4,520 mph (Mach 6.7). Under the lower fin is a dummy ramjet engine. It was intended to use the X-15A-2 for tests of an actual engine but this never happened.

The X-15A-2 with drop tanks and ablative coating is shown parked on the NASA ramp in front of the XB-70. These aircraft represent two different approaches to flight research. The X-15 was a research airplane in the purest sense, whereas the XB-70 was an experimental bomber intended for production but diverted to research when production was cancelled by changes in the Department of Defense's offensive doctrine.

High-altitude contrails frame the B-52 mothership as it carries the X-15 aloft for a research flight on 13 April 1960 on Air Force Maj. Robert M. White's first X-15 flight. The X-15s were air-launched so that they would have enough rocket fuel to reach their high speed and altitude test points. For this early research flight, the X-15 was equipped with a pair of XLR-11 rocket engines until the XLR-99 was available.

One of three X-15 rocket-powered research aircraft being carried aloft under the wing of its B-52 mothership. The X-15 was air launched from the B-52 so the rocket plane would have enough fuel to reach its high speed and altitude test points.

This photo illustrates how the X-15 rocket-powered aircraft was taken aloft under the wing of a B-52. Because of the large fuel consumption, the X-15 was air launched from a B-52 aircraft at 45,000 ft and a speed of about 500 mph. This was one of the early powered flights using a pair of XLR-11 engines (until the XLR-99 became available).

This U.S. Air Force photo shows the X-15 ship #3 (56-6672) in flight over the desert in the 1960s. Ship #3 made 65 flights during the program, attaining a top speed of Mach 5.65 and a maximum altitude of 354,200 feet. Only 10 of the 12 X-15 pilots flew Ship #3, and only eight of them earned their astronaut wings during the program. Robert White, Joseph Walker, Robert Rushworth, John B. McKay, Bill Dana, Joe Engle, Michael J. Adams, William H. Dana, Joe H. Engle, William J. "Pete" Knight.

This photo illustrates how the X-15 rocket powered aircraft was taken aloft under the wing of a B-52. Because of the large fuel consumption, the X-15 was air launched from a B-52 aircraft at 45,000 ft and a speed of about 500 mph. This photo was taken from one of the observation windows in the B-52 shortly before dropping the X-15.

NASA research pilot Milt Thompson stands next to a mock-up of X-15 number 3 that was later installed at the NASA Dryden Flight Research Center, Edwards, California. Milton O. Thompson was a research pilot, Chief Engineer and Director of Research Projects during a long career at the NASA Dryden Flight Research Center. Thompson was hired as an engineer at the flight research facility on 19 March 1956, when it was still under the auspices of NACA. He became a research pilot on 25 May 1958. Thompson was one of the 12 NASA, Air Force, and Navy pilots to fly the X-15 rocket-powered research aircraft between 1959 and 1968. He began flying X-15s on 29 October 1963. He flew the aircraft 14 times during the following two years, reaching a maximum speed of 3723

mph (Mach 5.42) and a peak altitude of 214,100 feet on separate flights. Thompson concluded his active flying career in 1968, becoming Director of Research Projects. In 1975 he was appointed Chief Engineer and retained the position until his death on 8 August 1993.

A series of ground and in-flight accidents occurred during the X-15's contractor program, fortunately without injuries or even greatly delaying the program. On 5 November 1959 a small engine fire -- always extremely hazardous in a volatile rocket airplane -- forced pilot Scott Crossfield to make an emergency landing on Rosamond Dry Lake. The X-15, not designed to land with fuel, came down with a heavy load of propellants and broke its back, grounding this particular X-15, ship #2 (56-6671), for three months.

On 9 November 1962, an engine failure forced Jack McKay, a NASA research pilot, to make an emergency landing at Mud Lake, Nevada, in the second X-15 (56-6671); its landing gear collapsed and the X-15 flipped over on its back. McKay was promptly rescued by an Air Force medical team standing by near the launch site, and eventually recovered to fly the X-15 again. But his injuries, more serious than at first thought, eventually forced his retirement from NASA. The aircraft was sent back to the manufacturer, where it underwent extensive repairs and modifications. It returned to Edwards in February 1964 as the X-15A-2, with a longer fuselage (52 ft 5 in) and external fuel tanks.

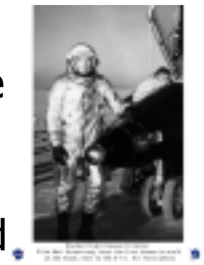
The X-15 flight crew, left to right; Air Force Captain Joseph H. Engle, Air Force Major Robert A. Rushworth, NASA pilot John B.

The X-15 pilots clown around in front of the #2 aircraft.From left to right: USAF Capt. Joseph Engle, USAF Maj. Robert Rushworth, NASA test pilot John.

Both the HL-10 and X-15A2, shown here parked beside one another on the NASA ramp in 1966, underwent modifications. The X-15 No. 2 had been damaged in a crash landing in November 1962. Subsequently, the fuselage was lengthened, and it was outfitted with two large drop tanks. These modifications allowed the X-15A-2 to reach the speed of Mach 6.7. On the HL-10, the stability problems that appeared on the first flight at the end of 1966 required a reshaping of the fins' leading edges to eliminate the separated airflow that was causing the unstable flight. By cambering the leading edges of the fins, the HL-10 team achieved attached flow and stable flight.

The X-15-3 (56-6672) research aircraft is secured by ground crew after landing on Rogers Dry Lakebed. The work of the X-15 team did not end with the landing of the aircraft. Once it had stopped on the lakebed, the pilot had to complete an extensive post-landing checklist. This involved recording instrument readings, pressures and temperatures, positioning switches, and shutting down systems. The pilot was then assisted from the aircraft, and a small ground crew depressurized the tanks before the rest of the ground crew finished their work on the aircraft.

Description: Dryden pilot Neil Armstrong is seen here next to the X-15 ship #1 (56-6670) after a research flight.



NASA test pilot Neil Armstrong is seen here next to the X-15 ship #1 (56-6670) after a research flight. Neil A. Armstrong joined the National Advisory Committee for Aeronautics (NACA) at the Lewis Flight Propulsion Laboratory (later NASA's Lewis Research Center, Cleveland, Ohio, and today the Glenn Research Center) in 1955. Later that year, he transferred to the NACA's High-Speed Flight Station (today, NASA?s Dryden Flight Research Center) at Edwards Air Force Base in California as an aeronautical research scientist and then as a pilot, a position he held until becoming an astronaut in 1962. He was one of nine NASA astronauts in the second class to be chosen. As a research pilot Armstrong served as project pilot on the F-100A and F-100C aircraft, F-101, and the F-104A. He also flew the X-1B, X-5, F-105, F-106, B-47, KC-135, and Paresev. He left Dryden with a total of over 2450 flying hours. He was a member of the USAF-NASA Dyna-Soar Pilot Consultant Group before the Dyna-Soar project was canceled, and studied X-20 Dyna-Soar approaches and abort maneuvers through use of the F-102A and F5D jet aircraft.

Major Robert M. White is seen here next to the X-15 aircraft after a research flight. White was one of the initial pilots selected for the X-15 program, representing the Air Force in the joint program with NASA, the Navy, and North American Aviation. Between 13 April 1960 and 14 December 1962, he made 16 flights in the rocket-powered aircraft. He was the first pilot to fly to Mach 4, 5, and 6 (respectively 4, 5, and 6 times the speed of sound). He also flew to the altitude of 314,750 feet on 17 July 1962, setting a world altitude record. This was 59.6 miles, significantly higher than the 50 miles the Air Force accepted as the beginning of space, qualifying White for astronaut wings.

NASA research pilot Milt Thompson stands next to the X-15 #3 ship after a research flight. Milton 0. Thompson was a research pilot, Chief Engineer and Director of Research Projects during a long career at the NASA Dryden Flight Research Center. Thompson was hired as an engineer at the Flight Research Facility on March 19, 1956, when it was still under the auspices of NACA. He became a research pilot on May 25, 1958. Thompson was one of the 12 NASA, Air Force, and Navy pilots to fly the X-15 rocket-powered research aircraft between 1959 and 1968. He began flying X-15s on October 29, 1963. He flew the aircraft 14 times during the following two years, reaching a maximum speed of 3723 mph (Mach 5.42) and a peak altitude of 214,100 feet on separate flights. Thompson concluded his active flying career in 1968, becoming Director of Research Projects. In 1975 he was appointed Chief Engineer and retained the position until his death on August 8, 1993.

Captain Joe Engle is seen here next to the X-15-2 (56-6671) rocket-powered research aircraft after a flight. Engle made 16 flights in the X-15 between October 7, 1963, and October 14, 1965. Three of the flights, on June 29, August 10, and October 14, 1965, were above 50 miles, qualifying him for astronaut wings under the Air Force definition. (NASA followed the international definition of space as starting at 62 miles.) Engle was selected as a NASA astronaut in 1966, making him the only person who had flown in space before being selected as an astronaut. First assigned to the Apollo program, he served on the support crew for Apollo X and then as backup lunar module pilot for Apollo XIV. In 1977, he was commander of one of two crews who were launched from atop a modified Boeing 747 in order to conduct approach and landing tests with the Space Shuttle Enterprise. Then in November 1981, he commanded the second flight of the Shuttle Columbia and manually flew the re-entry--performing 29 flight test maneuvers--from Mach 25 through landing roll out. This was the first and, so far, only time that a winged aerospace vehicle has been manually flown from orbit through landing. He accumulated the last of his 224 hours in space when he commanded the Shuttle Discovery during STS-51-I in August of 1985.

NASA research pilot Bill Dana is seen here next to the X-15 #3 rocket-powered aircraft after a flight. William H. Dana is Chief Engineer at NASA's Dryden Flight Research Center, Edwards, California. Formerly an aerospace research pilot at Dryden, Dana flew the F-15 HiDEC research aircraft and the Advanced Fighter Technology Integration/F-16 aircraft.

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Air Force test pilot Robert A. Rushworth is shown in an X-15. He was selected for the X-15 program in 1958, and made his first flight on November 4, 1960. Over the next six years, he made 34 flights in the X-15, the most of any pilot. This included a flight to an altitude of 285,000 feet, made on June 27, 1963. This flight above 50 miles qualified Rushworth for astronaut wings. On a later X-15 flight, he was awarded a Distinguished Flying Cross for successfully landing an X-15 after its nose wheel extended while flying at nearly Mach 5. He made his final X-15 flight on July 1, 1966, then returned to regular Air Force duties. These included a tour in Vietnam as an F-4 pilot, flying 189 combat missions. He also served as the Commander of the Air Force Flight Test Center at Edwards AFB, and as the Commander of the Air Force Test and Evaluation Center at Kirtland AFB. At the time of his retirement as a major general, he was Vice Commander, Aeronautical Systems Division, Air Force Systems Command, at Wright-Patterson AFB. Rushworth flew C-47s and C-46s as a transport pilot in World War II, as well as F-80Cs, F-101s, TF-102s, F-104s, F-105s, F-106s, and F-4s. He died on March 17, 1993.

Mod II radar system used by the U.S. Air Force at Cape Canaveral prior their modification and use on the NASA High Range

THE HIGH RANGE

The Mod II radar we used on the NASA High Range for the X-15, XB-70, Blackbird, and Lifting Body tests in the 1950s and 60s was a World War II vintage S-band radar system used previously by the U.S. Air Force at Cape Canaveral for missile and rocket launches. Originally, this S-band radar had a range of only 60 miles.

Modified for use on the High Range, the range of the radar was basically limited by the strength of the transponder on the target aircraft and the curvature of the earth. During a tracking mission, the target cursor on the radar scope would travel to the end of the base line of the scope every 60-miles at which time it would disappear for a moment and then reappear at the beginning of the base line. The wiring was so old that the insulation would crumble off the wiring at the least disturbance. Often the scope would black out completely because of an intermittent wiring problem. Illumination could usually be regained by the operator banging on the chassis with the palm of his hand.

During an overhead track, the Mod II elevated until it hit a stop, at which time the radar had to slew 160 degrees and then resume track. This was a particularly stressful moment at the Beatty site as the X-15 would be passing almost directly overhead at a Mach-6 speed. The range and elevation indicator dials would be spinning too fast to read. If for some reason the radar failed to regain auto track, the X-15 would be in its landing maneuver at Edwards AFB before the Beatty radar operator could physically align the radar on the plane to resume track.

It is a credit to North American for its production of a superb aircraft, and to NASA, its High Range personnel and contractor support personnel that the X-15 program paved the way for space exploration and in the process produced several of the first United States astronauts as the X-15 surpassed 50 miles altitude during a mission. The X-15 was flown over a period of nearly 10 years -- June 1959 to Oct. 1968 -- and set the world's unofficial speed and altitude records of 4,520 mph (Mach 6.7) and 354,200 ft.

DRYDEN/EDWARDS

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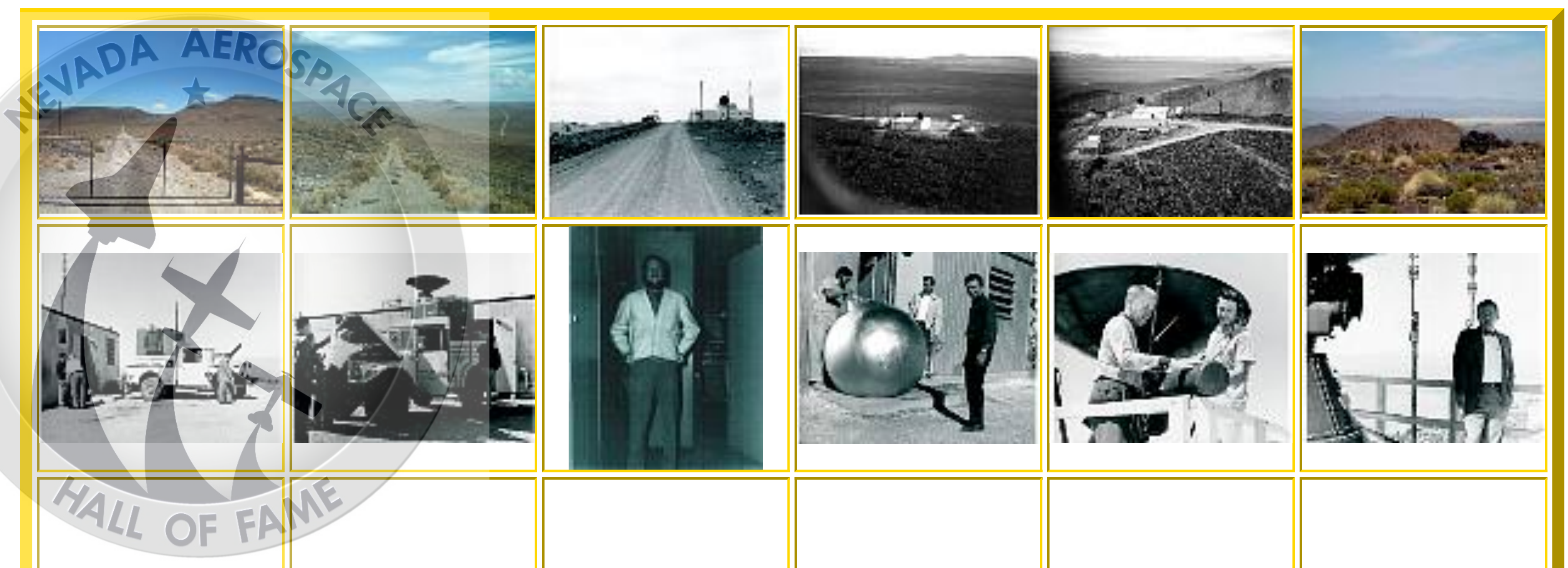
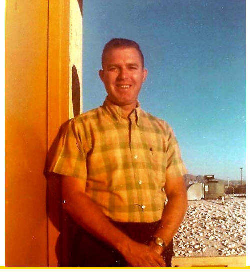
BEATTY, NEVADA





ELY, NEVADA





The X-15 flew to an altitude of 354,000 feet and reached a Mach number of 6.70. It flew its last flight over thirty years ago, but to this day, except for the Space Shuttle no aircraft has flown half as high nor half as fast. The late Dr. Hugh L. Dryden termed it "the most successful research airplane in history."

The X-15's beginnings were in 1952. It was the year of the first flight of the YB-52, and the aeronautical community was struggling to advance aircraft speeds from Mach 1.5 to Mach 2. Men of vision, however, already were looking to the higher speeds and altitudes that would eventually take us to orbital flight. For it was that year that the NACA Committee on Aeronautics recommended an increase in research dealing with flight to speeds of Mach 10 or 12 and to altitudes from 12 to 50 miles.

In 1954, NACA submitted to the Air Force-Navy-NACA research airplane program a technical proposal for a hypersonic research airplane. The plan was accepted and in December 1954, the Air Force issued invitations to industry for the design and manufacture of a hypersonic research airplane. Several contractors submitted proposals with maximum speeds in the Mach 6 to Mach 7 range.

The ultimate winner of the contract was North American Aviation, and the result was the X-15. The X-15 program called for the production of three aircraft designed for a speed of Mach 6.6 and an altitude of 250,000 feet. The Mach 6.6 represented the maximum speed that state of the art structures could support; the 250,000 foot altitude was an arbitrary design point which would force adequate attention to exo-atmospheric control and to reentry techniques.

The X-15 was 50 feet long and had a wingspan of 22 feet. It (SLIDE 3) weighed 33,000 pounds at launch and 15,000 pounds empty. Its flight control surfaces were hydraulically actuated and included all-moveable elevators, all-moveable upper and lower rudders (the lower rudder extended below the landing gear; it had to be jettisoned before landing), speed brakes on the aft end of the fixed portion of the vertical fins, and landing flaps on the trailing edge of the wing. There were no ailerons; roll control was achieved by differential deflection of the horizontal tail.

All three X-15's were delivered with simple rate-feedback damping in all axes. The number three X-15, however, was extensively damaged during a ground engine run before it ever flew; when it was rebuilt it was fitted with a self-adaptive flight control system which included command augmentation, self-adaptive damper gains, several autopilot modes, and blended aerodynamic and ballistic controls.

Two other steam turbines, called auxiliary power units, each furnished hydraulic pressure and the electrical power for the X-15. Their propellant also was decomposed hydrogen peroxide. Liquid nitrogen was used for cooling the payload bay, cockpit, windshields, and nose. Steam rockets in the nose and wings provided altitude control when out of the atmosphere.

The X-15 had three flight controllers. The center stick provided conventional pitch and roll control, and was intended for use after engine burnout. Mechanically linked to the center stick was a right hand controller used during the boost. When the pilot was using the side controller, the back of his right elbow was braced to not allow aft movement; this prevented the mass of the pilot's forearm and hand from causing spurious pitch inputs in the acceleration field existing during boost. On the left side of the cockpit was a three-axis ballistic controller, which was mechanically linked to steam rockets in the nose and wings.

On the instrument panel was an attitude indicator whose source was inertially derived. Also provided were inertial velocity, altitude, and rate-of-climb. Barometric instruments included an altimeter and a combined Mach-airspeed indicator; these instruments were usable only below about 75,000 feet and were used mainly in the traffic pattern. An angle of attack and a sideslip indicator were provided; the source of these two instruments was selectable, inertial for high altitude flight and barometric for the end of the mission.

The X-15 was actually the second stage of a two-stage system. The first stage was a B-52 bomber, specially modified for the program, which carried the X-15 uprange into Nevada, pointed it towards Edwards, and launched it at 45,000 feet and 0.8 Mach number.

The X-15 was usually launched about 200 miles from Edwards. The engine was lit immediately after launch and burned for about 85 seconds. During that period, it would boost the X-15 to an altitude of 160,000 feel and a Mach Number of 5.4. The X-15 would then coast to 250,000 feet, reenter, and glide to a landing on the dry lake at Edwards. A typical X-15 flight lasted eleven minutes, including about four minutes in the traffic pattern.

The X-15 first flew on June 8, 1959, and within four years had completed all the objectives of the original research program. It reached a Mach number of 6.06, which due to weight growth was less than the Mach 6.6 design speed, but it also reached an altitude of 354,000 feet, some 40 percent higher than the program goal of 250,000 feet. The altitude capability was made possible by the blended aerodynamic and reaction controls of the self-adaptive flight control system in the X-15 No. 3. (Only X-15 No. 3 flew significantly above 250,000 feet.)

Problems anticipated for the X-15 prior to the first flight.

The mechanics of atmospheric exit and entry were quite straightforward. The pilot flew a constant pitch altitude to engine burnout, then an angle of attack schedule---a low angle of attack to peak altitude, and a high angle of attack for reentry. Reentry angle of attack varied from 15 to 26 degrees, depending on peak altitude.

There were some aeromedical effects of interest during boost. One was the ability of the pilots to function in the acceleration during boost. After engine light, the pilot was under 2g chest-to-back acceleration which increased to about 4g at burnout. The pilots felt that four gs was about enough. Milt Thompson once stated that "the X-15 was the only aircraft I ever flew where I was glad when the engine quit. "

The fact that the X-15 pilots were willing to call 4gs of axial acceleration a limit when current-day fighter pilots fly and fight in much higher normal acceleration environments may have been due to another phenomenon concerning X-15 power-on flight----the phantom pitch rate perceived during the boost. In the absence of a horizon reference, the pilot tends to define "down" as the way acceleration is forcing him. When the X-15 pilot lost sight of the horizon during pullup, the acceleration along the flight path gave the pilot the sensation of pitching steeply up. As the acceleration increased during fuel burn, the pilot had the sensation that the X-15 was rotating even more steeply up. This was a fundamental sensory illusion; there was no cure for it. Strict reference to the flight instruments was required until engine shutdown to prevent the pitch rate illusion from ruining the flight profile.

Entry was a less-demanding pilot task. There was no acceleration due to thrust, and the horizon was in view throughout. At constant angle of attack, the normal acceleration gradually built up to 5gs and then was maintained there (usually for a period of about 15 seconds) until the X-15 had broken its fall. It might be noted that the X-15 pressure suit was equipped with an integral g suit.

Control Outside the Atmosphere There were no serious problems controlling the X-15 using the ballistic control rockets. Care had to be exercised to keep angular rates small, because the task could get confusing while attempting to control all three axes simultaneously. The main problem with ballistic flight was that the airplane was neutrally stable; the pilot was the only thing keeping the X-15 pointing down the flight path. X-15 No. 3 had aerodynamic and ballistic controls blended automatically through the autopilot, one of whose features was heading-hold mode; so that as far as the pilot was concerned, X-15 No. 3 was directionally stable while ballistic.

Control at Zero Gravity It turned out there were no control problems at zero gravity, nor were there any other problems related to weightlessness. There was no pilot nausea, as later occurred in the Apollo program. There was one humorous incident where the pilot hit the latch on his checklist binder while shutting down the engine; he thereby released 27 pages of checklist that floated around the cockpit for the two minutes before the weightlessness ended.

Aerodynamic and Structural Heating During the entire program, the X-15s were exposed to surface temperatures as high as 1350 degrees F and all the airplanes exhibited minor buckling of the exterior skin. During the rocket boost phase of the flight, when the aircraft was accelerating and heating rapidly, the pilot could hear this skin buckling. As Joe Walker observed, "The airplane crackled like a hot stove."

The leading edges of the wing were formed in several pieces and had small slots between segments to allow thermal growth. These slots tripped the boundary layer and caused high temperature and skin buckling downstream of the slots. The slots were eventually capped and an additional rivet was added behind the slot, curing the problem.

On two occasions the right outside windowpane crazed forcing the pilot to fly and land with only left-hand vision. Buckling of the window frame caused this crazing. The Inconel frame was replaced by one of titanium, which has a lesser thermal expansion and which prevented further recurrences of window crazing

Simulation: For planning X-15 flights and for pilot practice, extensive use was made of a fixed base analog simulator. Every flight was preceded by ten or twenty hours of simulation of normal and emergency procedures.

The simulator had to be continually updated with data gathered in flight. For example, early simulation based on wind tunnel data indicated that the X-15 would be flyable with the lower rudder turned on and the roll damper turned off. Flight test proved this not to be the case. When the roll damper was turned off, a test also revealed that the lower rudder was not required for directional stability. The lower rudder was discarded, the X-15 then became stable even with a roll damper failure, and the simulator was updated to reflect the actual aircraft characteristics.

Landing Prior to the X-15 flight program there was considerable reservation about the pilots' ability to consistently land a power-off, low lift-drag ratio airplane. The X-15, however, had good handling qualities and large variable deflection speed brakes and it proved easy to land.

All the pilots used a circling approach that was commenced at 30,000 to 50,000 feet above the runway and they stayed high on profile until it was assured that they would reach the runway, at which time speed brakes were used to descend onto a nominal glideslope. The landing gear was left retracted, for drag reduction, until the landing flare was complete and the aircraft was in level flight.

Three X-15s made 199 flights during a research program which lasted from 1960 through 1968. It was a daring, yet highly successful program that resulted in hundreds of technical reports. It made contributions to the NASA space program of the 1960s and also on the design and flight of the Space Shuttle many years later.

An unofficial motto of flight research in the 1940s and 1950s was "higher and faster." By the late 1950s the last frontier of that goal was hypersonic flight (Mach 5+) to the edge of space. It would require a huge leap in aeronautical technology, life support systems and flight planning.

The North American X-15 rocket plane was built to meet that challenge. It was designed to fly at speeds up to Mach 6, and altitudes up to 250,000 ft. The aircraft went on to reach a maximum speed of Mach 6.7 and a maximum altitude of 354,200 ft. Looking at it another way, Mach 6 is about one mile per second, and flight above 265,000 ft. qualifies an Air Force pilot for astronaut wings.

The X-15 was a rocket-powered aircraft 50 ft long with a wingspan of 22 ft. It was a missile-shaped vehicle with an unusual wedge-shaped vertical tail, thin stubby wings, and unique side fairings that extended along the side of the fuselage. The X-15 weighed about 14,000 lbs empty and approximately 34,000 lbs at launch. The XLR-99 rocket engine, manufactured by Thiokol Chemical Corp., was pilot controlled and was capable of developing 57,000 lbs of thrust.

North American Aviation built three X-15 aircraft for the program. The X-15 research aircraft was developed to provide in-flight information and data on aerodynamics, structures, flight controls, and the physiological aspects of high-speed, high-altitude flight. A follow-on program used the aircraft as a testbed to carry various scientific experiments beyond the Earth's atmosphere on a repeated basis.

For flight in the dense air of the usable atmosphere, the X-15 used conventional aerodynamic controls such as rudders on the vertical stabilizers to control yaw and movable horizontal stabilizers to control pitch when moving in synchronization or roll when moved differentially. For flight in the thin air outside of the appreciable Earth's atmosphere, the X-15 used a reaction control system. Hydrogen peroxide thrust rockets located on the nose of the aircraft provided pitch and yaw control. Those on the wings controlled roll.

Because of the large fuel consumption, the X-15 was air launched from a B-52 aircraft at 45,000 ft and a speed of about 500 mph. Depending on the mission, the rocket engine provided thrust for the first 80 to 120 sec of flight. The remainder of the normal 10 to 11 min. flight was powerless and ended with a 200-mph glide landing. Generally, one of two types of X-15 flight profiles was used; a high-altitude flight plan that called for the pilot to maintain a steep rate of climb, or a speed profile that called for the pilot to push over and maintain a level altitude. The plane was air launched by NASA's converted B-52 at 45,000 feet and a speed of 500 mph.

Generally there were two types of flight profiles: high-speed, or high-altitude. High-speed flights were usually done below an altitude of 100,000 feet and flown as a conventional airplane using aerodynamic controls. High-altitude flights began with a steep, full-power climb to leave the atmosphere, followed by up to two minutes of "coasting up" to the peak altitude after the engine was shut down. "Weightless" flight would last for 2 - 5 minutes as it made a ballistic arc before reentering the atmosphere.

A reaction control system was used to maintain attitude above the atmosphere. The reaction controls employed hydrogen peroxide thrusters located on the nose and wings. Depending on the mission, the rocket engine provided thrust for the first 80 to 120 seconds of flight. The remainder of the normal 8- to 12-minute flight was without power and ended in a 200-mph glide landing.

Because the nose landing wheel lacked steering and the main landing gear employed skids, the X-15 had to land on a dry lakebed. The Rogers Dry Lake adjacent to Edwards and Dryden was the intended landing location for all flights, but there were numerous emergency lakebeds selected in advance for emergency landings.

The X-15 program made many accomplishments, here is list of some of its contributions to space flight: First application of hypersonic theory and wind tunnel work to an actual flight vehicle. First use of reaction controls for attitude control in space. First reusable super alloy structure capable of withstanding the temperatures and thermal gradients of hypersonic reentry. Development of [a servo-actuated ball] nose flow direction sensor for operation over an extreme range of dynamic pressure and a stagnation air temperature of 1,900 degrees Fahrenheit [for accurate measurement of air speed and flow angle at supersonic and hypersonic speeds].

Development of the first practical full pressure suit for pilot protection in space. Development of inertial flight data systems capable of functioning in a high dynamic pressure and space environment. Discovery that hypersonic boundary layer flow is turbulent and not laminar. Discovery that turbulent heating rates are significantly lower than had been predicted by theory. First direct measurement of hypersonic skin friction and discovery that skin friction is lower than had been predicted. Discovery of hot spots generated by surface irregularities. [These last 4 discoveries led to improved design tools for future hypersonic vehicles, including the Space Shuttle.] Discovery of methods to correlate base drag measurements with tunnel test results so as to correct wind tunnel data [and thereby improve design criteria for future air- and spacecraft].

First application of energy-management techniques [for the positioning of the vehicle for landing; these were essential for the landing of the Space Shuttle and all future reusable launch vehicles following their reentry from space.] Use of the three X-15 aircraft as testbeds carrying a wide variety of experimental packages.

More intangibly but no less importantly, in the words of the distinguished Langley aeronautical researcher John Becker, who had been an early advocate of the X-15 program, the X-15 project led to "the acquisition of new manned [today, we would say piloted] aerospace flight 'know how' by many teams in government and industry. They had to learn to work together, face up to unprecedented problems, develop solutions, and make this first manned aerospace project work. These teams were an important national asset in the ensuing space programs."

The X-15 was flown over a period of nearly 10 years -- June 1959 to Oct. 1968 -- and set the world's unofficial speed and altitude records of 4,520 mph (Mach 6.7) and 354,200 ft in a program to investigate all aspects of piloted hypersonic flight. Information gained from the highly successful X-15 program contributed to the development of the Mercury, Gemini, and Apollo piloted spaceflight programs, and also the Space Shuttle program.

The North American Aviation X-15s made a total of 199 flights. There were 196 successful landings in the program, and the two landing accidents that occurred were related to system or structural failures and not to pilot error. X-15-1, serial number 56-6670, is now located at the National Air and Space Museum, Washington DC. North American X-15A-2, serial number 56-6671, is at the United States Air Force Museum, Wright-Patterson AFB, Ohio. X-15-3, serial number 56-6672, crashed on 15 November 1967, resulting in the death of Maj. Michael J. Adams. Parts of the X-15-3 are on display at the Air Force Flight Test Center Museum at Edwards AFB, and the San Diego Aerospace Museum, San Diego, California.

-- The X-15 program made many accomplishments, some of which include:

First use of a full-pressure suit for spaceflight.

First use of reaction controls for maneuvering in space.

First use of a flight control system that automatically blended aerodynamic and reaction controls.

Development of thermal protection for hypersonic reentry.

Development of the first large, restartable, and throttleable rocket engine.

Development of inertial flight data systems capable of functioning in a high-dynamic-pressure and space environment.

Demonstration of a pilot's ability to operate in "micro-gravity".

Demonstration of the first piloted reentry-to-landing from space.

Acquisition of hypersonic acoustic measurements, which influenced structural design criteria for Mercury capsule.

Verification of the validity of hypersonic wind tunnel data, which were later used in the design of the Space Shuttle.

X-15 Flight Summary

X-15 Pilots in chronological order with total flights:

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

Fastest speed (basic aircraft) was 4,104 mph (Mach 6.06) on flight 1-30-51 with pilot Joe Walker.

Fastest speed with tanks was 4,520 mph (Mach 6.70) on flight 2-53-97 with pilot William Knight.

Highest altitude was 354,200 ft (67 miles) on flight 3-22-36 with Joseph Walker.
Total flight time was 30 hr, 13 min. and 49.2 sec.
Total distance flown was 41,763.8 miles (statute).
Total flights of the X-15 was 199 between 1959 and 1968.
Hours above Mach (Cumulative):
Mach 1 - 18 hr, 23 min. and 11.6 sec
Mach 2 - 12 hr, 13 min., and 50 sec
Mach 3 - 8 hr, 51 min., and 12.8 sec
Mach 4 - 5 hr, 57 min., and 23.8 sec
Mach 5 - 1 hr, 27 min., and 15.8 sec
Mach 6 - 1 min. and 16.8 sec