

X-15 TO THE EDGE OF SPACE...

SENSATIONAL, ICONIC, GROUNDBREAKING. The X-15 hypersonic research airplane significantly extended the frontiers of flight. It was a program of outstanding engineering achievements, jaw-dropping performance characteristics, and extraordinary human endeavor. During a 15-year journey of discovery, the X-15 became the fastest and highest-flying piloted winged airplane of its time. Its discoveries set NASA on a direct course for the exploration of space.

National Aeronautics and Space Administration



354,200 ft **1,325° F** **4,520 mph** **8-g**

HIGHEST ALTITUDE ATTAINED FOR A WINGED AIRCRAFT (THAT'S 67 MILES HIGH!) AND AN ACHIEVEMENT NOT SURPASSED UNTIL 2004

THE PEAK SURFACE TEMPERATURE OF A TEST PANEL ON THE X-15 DURING A MACH 5 MISSION

TOP SPEED OF MACH 6.70 — AN ACHIEVEMENT UNBROKEN FOR 41 YEARS

THE G-FORCE EXPERIENCED BY X-15 PILOTS ON SOME FLIGHTS DURING REENTRY INTO EARTH'S ATMOSPHERE



A WING AND A PRAYER

Test pilot Scott Crossfield helped to design the ejection seat, which enabled safe ejection at speeds up to Mach 8, in any attitude and at any altitude up to 200,000 feet. After the canopy was jettisoned, the seat fired upward and, once clear of the aircraft, deployed a pair of fold-out fins and telescoping booms for stabilization. A face-heater battery activated to keep the pilot's vision clear of ice, and oxygen was supplied from two under-seat tanks. Despite the seat's sophistication, none of the pilots wanted to see it used on a mission.



THE OUTER SKIN OF THE X-15 WAS MADE OF A NICKEL-CHROMIUM ALLOY CALLED INCONEL X. EMPLOYED IN A HOT STRUCTURE THAT WAS CAPABLE OF WITHSTANDING TEMPERATURES IN EXCESS OF 2,000°F, THE BEAMS AND SPARS OF THE WINGS AND THE RING STRUCTURE OF THE FUSELAGE WERE CONSTRUCTED FROM STRONG TITANIUM-MANGANESE ALLOY.

It was arguably the most successful aeronautical research effort in history. Between June 1959 and October 1968, NASA's X-15 hypersonic research flights rewrote the rule book of conventional flight and spawned an extraordinary legacy that lives on today.

TRIUMPHS AND TRAGEDY

The achievements of the X-15 are breathtaking. Not only did the aircraft create history with its speed and altitude. It gave birth to some amazing successes—the first extensive use of simulation as an engineering tool, first full-pressure suit for pilot protection in space, first application of hypersonic theory to a flight vehicle. The list goes on. However, the program also experienced its share of setbacks and one tragic loss.

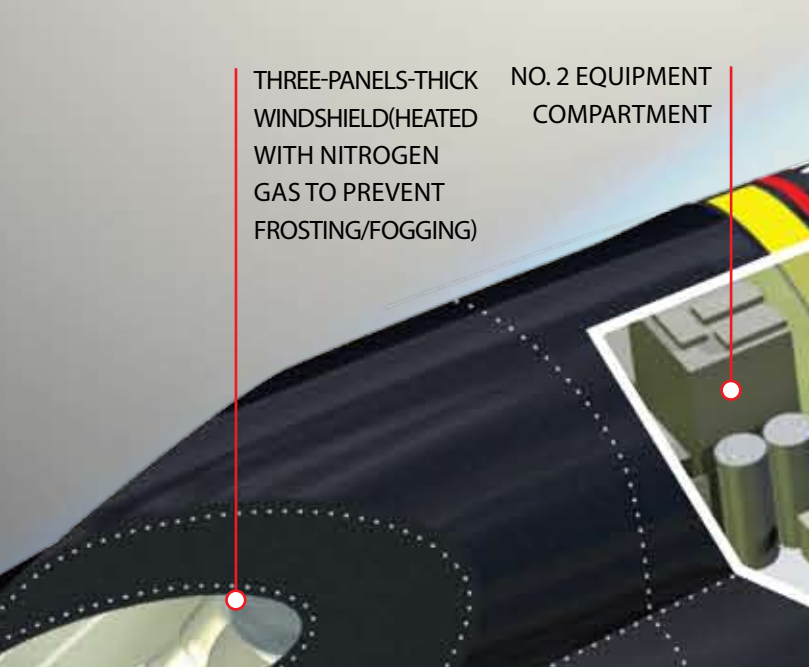
WHITE LIGHTNING

The X-15A-2 (pictured above) was designed for maximum speed. Two external tanks for liquid ammonia and liquid oxygen provided an extra 60 seconds of engine burn and, in theory, could power the rocket plane to speeds well in excess of Mach 7. The white color of the aircraft was due to the application of an ablative coating designed to protect the structure from the high temperatures that would be generated at such speeds. The fuselage was extended by 29 inches to carry liquid hydrogen for a planned supersonic combustion ramjet (scramjet) that was flown in mockup form but never actually tested. In the hands of pilot Pete Knight, the X-15A-2 reached Mach 6.70 (4,520 mph), the fastest flight of the X-15 program.

The world's first piloted vehicle designed to study the realms of hypersonic flight—an experimental aircraft of mind-boggling performance—was conceived by a joint team from NASA, the U.S. Air Force, the U.S. Navy and North American Aviation. The goal was to fly at Mach 6—six times faster than the X-1 aircraft that exceeded the sound barrier a decade earlier. The team aimed to fly the X-15 at an altitude of 250,000 ft—nearly 50 miles above Earth's surface. By the time NASA test pilot Bill Dana brought the 199th and final X-15 flight to a stop on the parched lake bed of Edwards Air Force Base in California on October 24, 1968, these goals had been achieved.

IN CONTEXT

"X" means "experimental." The first "X" designation went to the Bell X-1, which, on October 14, 1947, became the first airplane to break the sound barrier in level flight. Since then, more than 50 different major research designs have used the "X" designation. Although not every "X" vehicle became a flying prototype, every design proved to be a highly valuable research tool for advancing knowledge of aerodynamics and astronautics.

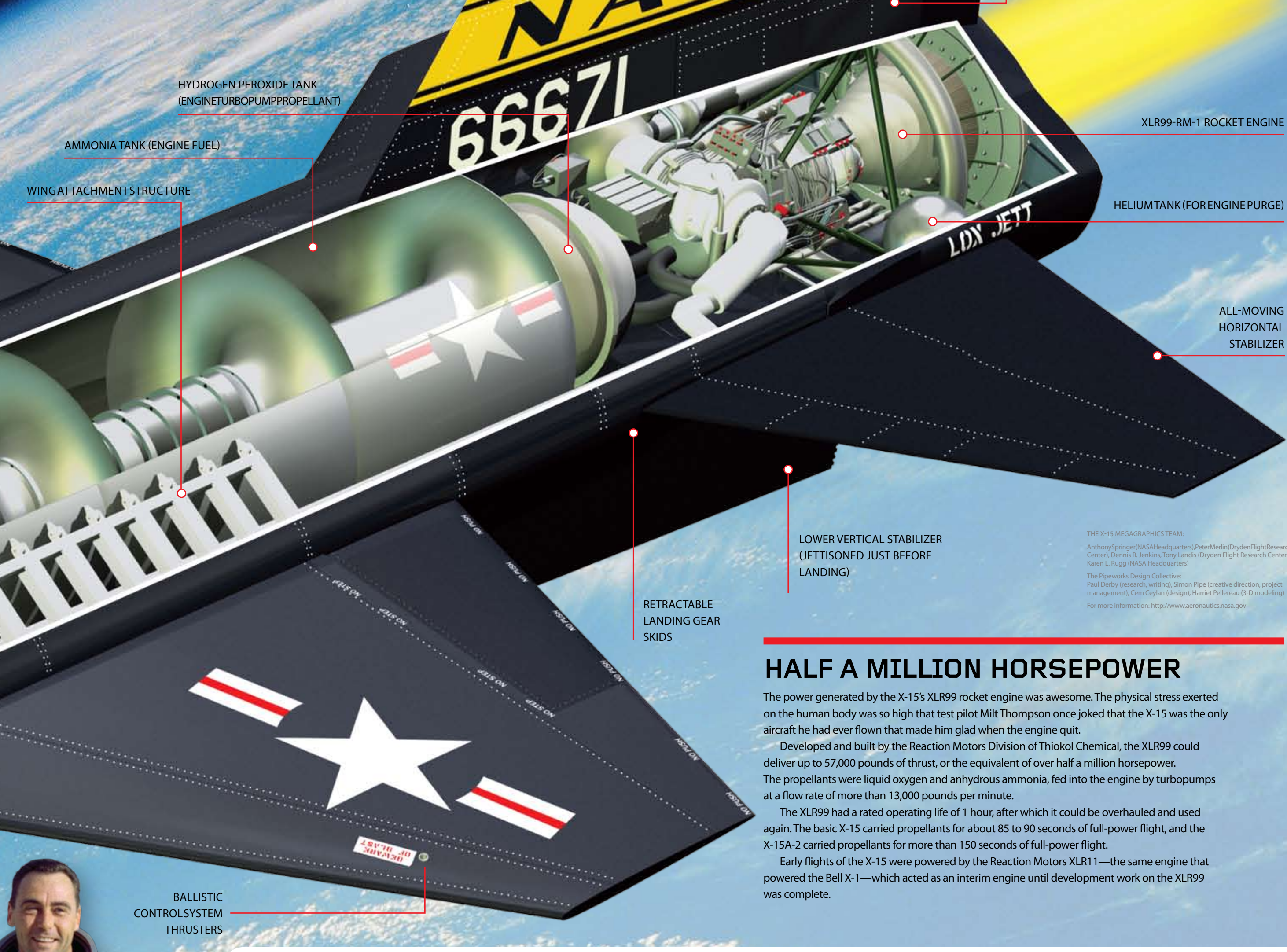
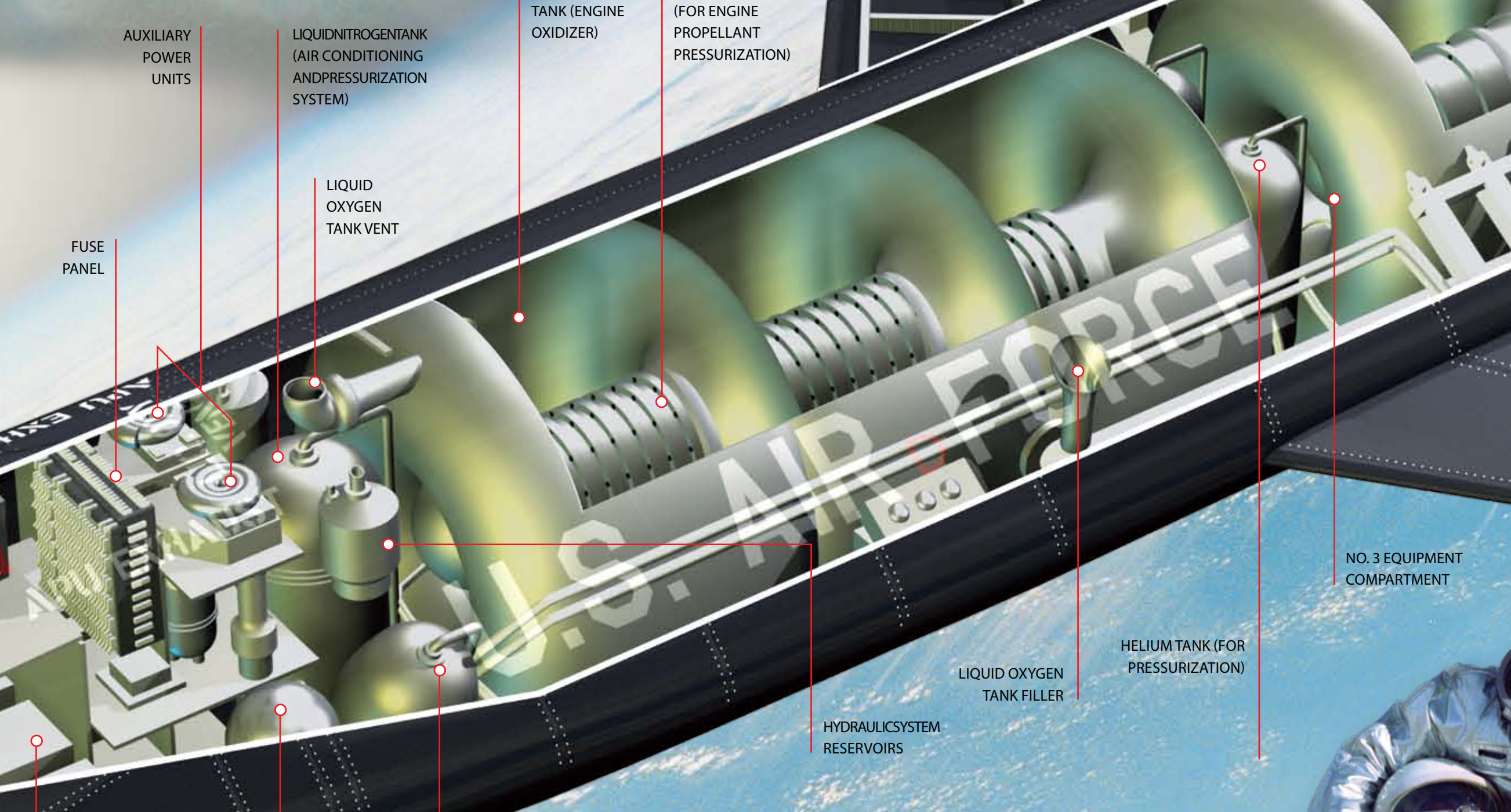


The X-15 flew faster and higher than any other piloted winged vehicle other than the space shuttle. On separate flights, the X-15 reached Mach 6.70 (4,520 mph) and 354,200 feet. The program could have broken every speed and altitude record in the books, but that was not the goal. The sole purpose of the X-15 was to enable research at hypersonic velocities and at the edge of space.

NASA continues to invest in next-generation technologies to ensure that the legacy of the X-15 lives on.

THE LEGACY

The X-15 program yielded a treasure trove of valuable data and fresh understanding. Perhaps most critically, it provided a major technological stepping stone to space. The Mercury, Gemini, and Apollo programs all benefited from the X-15 research and, every time a space shuttle returns from orbit, it does so using knowledge derived from the X-15. The X-15 demonstrated for the first time that pilots could fly rocket-powered aircraft out of Earth's atmosphere, control them successfully in an airless environment, reenter the atmosphere and perform a precision landing at a predetermined site. In other words, it invented what eventually became the basic flight profile for a space shuttle mission.



A SERVO-ACTUATED BALL NOSE FLOW DIRECTION SENSOR PROVIDED ACCURATE MEASUREMENT OF ANGLE OF ATTACK AND ANGLE OF SIDESLIP AT SUPERSONIC AND HYPERSONIC VELOCITIES.

NO. 1 EQUIPMENT COMPARTMENT

TELEMETRY RECORDERS

AREA FOR EXPERIMENTS

TELEMETRY RECORDERS

NO. 2 EQUIPMENT COMPARTMENT

SKYLIGHT HATCH

NO. 2 EQUIPMENT COMPARTMENT

THREE-PANEL THICK WINDSHIELD HEATED WITH NITROGEN GAS TO PREVENT FROSTING/FOGGING

LIQUID OXYGEN TANK (ENGINE OXIDIZER)

LIQUID NITROGEN TANK (AIR CONDITIONING AND PRESSURIZATION SYSTEM)

LIQUID OXYGEN TANK FILLER

HYDRAULIC SYSTEM RESERVOIRS

HELIUM TANK (FOR ENGINE PROPELLANT PRESSURIZATION)

HELIUM TANK (FOR PRESSURIZATION)

NO. 3 EQUIPMENT COMPARTMENT

BALLISTIC CONTROL SYSTEM THRUSTERS

RETRACTABLE LANDING GEAR SKIDS

LOWER VERTICAL STABILIZER (JET-TENSIONED JUST BEFORE LANDING)

AMMONIA TANK (ENGINE FUEL)

WING ATTACHMENT STRUCTURE

WING FLAP

HYDROGEN PEROXIDE TANK (ENGINE TURBOPROPPELLANT)

MOVABLE UPPER VERTICAL STABILIZER

UPPER SPEED BRAKE

XL9R99-HM-1 ROCKET ENGINE

HELIUM TANK (FOR ENGINE PURGE)

ALL-MOVING HORIZONTAL STABILIZER

FLYING AT THE EDGE

To protect the pilot and sensitive electronics from the ferocious heat of hypersonic flight, the pressurized aluminum cockpit and equipment bay were insulated from the outer Inconel X shell by a radiation shield and insulation blanket.

The X-15 included one of the first inertial navigation systems (called a "stable platform") to let the pilot know his precise position over the High Range, and a sophisticated Stability Augmentation System to help him maintain precise control of the aircraft.

Above Earth's atmosphere, reaction controls kept the aircraft stable. Hand controllers in the cockpit were linked to small hydrogen peroxide thrusters at the nose for pitch and yaw control, and on each outer wing to control roll.

The most dangerous part of a mission was the descent. As the pilot switched from theater control to traditional "stick-and-rudder" flying, the X-15 became a 15,000-pound unpowered hypersonic glider glowing red-hot as it decelerated from 4,000 mph to 200 mph. With only one shot at landing, there was simply no room for error.



1. TANK PRESSURIZATION SELECTOR
2. ENGINE THROTTLE
3. ALTITUDE
4. AIRSPEED/MACH INDICATOR
5. ACCELEROMETER
6. CONVENTIONAL CENTER STICK (IMPOSED THE AERODYNAMIC CONTROL SURFACES)
7. VERTICAL VELOCITY INDICATOR
8. SYSTEM WARNING LIGHTS
9. CANOPY EMERGENCY JETTISON HANDLE

THE CARRIER AIRCRAFT

Before the X-15 could negotiate any mission successfully, a mother ship had to carry the research airplane to high altitude since the X-15 did not have enough propellant to take off from the ground. A pair of mighty Boeing B-52 Stratofortress aircraft took the X-15 under their wings. The NB-52A was dubbed "The High and Mighty One" and the NB-52B "The Challenger."

The B-52 carried the X-15 to a launch altitude of approximately 45,000 feet. When the X-15 pilot hit the launch switch, the research airplane dropped away from the B-52, falling toward Earth just until the rocket engine ignited and then accelerating to Mach 5, or even Mach 6.

The B-52X-15 combination made 336 flights, including 199 successful launches of the X-15. Of the others, 12 were planned "captive" missions in which the X-15 remained attached to the B-52 to check out various systems, and 125 flight attempts ended as aborts in which the X-15 remained safely under the B-52 wing until the pair returned to Edwards Air Force Base.

So successful were the mother ships that the NB-52B—better known as "NASA 008"—served for nearly 50 years until its retirement in December 2004. Maintenance crews treated the venerable aircraft more like a classic car than an aging bomber. It ended its career as it began—in hypersonics.

During its last mission, the NASA 008 launched the unpowered X-43A scramjet research vehicle on a flight that reached a velocity of Mach 9.60.



FULL-PRESSURE SUIT

The full-pressure suit worn by X-15 pilots to protect them from the effects of high-altitude flight was revolutionary. Previous pressure suits were cumbersome, virtually immobilized the pilot, and were mostly ineffective. Fresh thinking was required.

The answer was a groundbreaking development by the David Clark Company that resulted in the MC-2 suit. The introduction of an inner nylon mesh called "link-net" radically improved mobility and provided much improved protection against the harsh environment.

The suit was integral to the pilot's environment. It provided cooling and ventilation; supplied oxygen; and contained parachute harness, a microphone, oxygen and pressure regulators. Wsors were heated for the same reason as car windshields—to prevent fogging.

A total of 36 X-15 flights used the original MC-2 suit, while the remainder used the newer AP225-2, also developed by the David Clark Company. Each suit was custom-made for a particular X-15 pilot. Variants of this design would become the standard full-pressure suits used across all U.S. military and NASA programs.

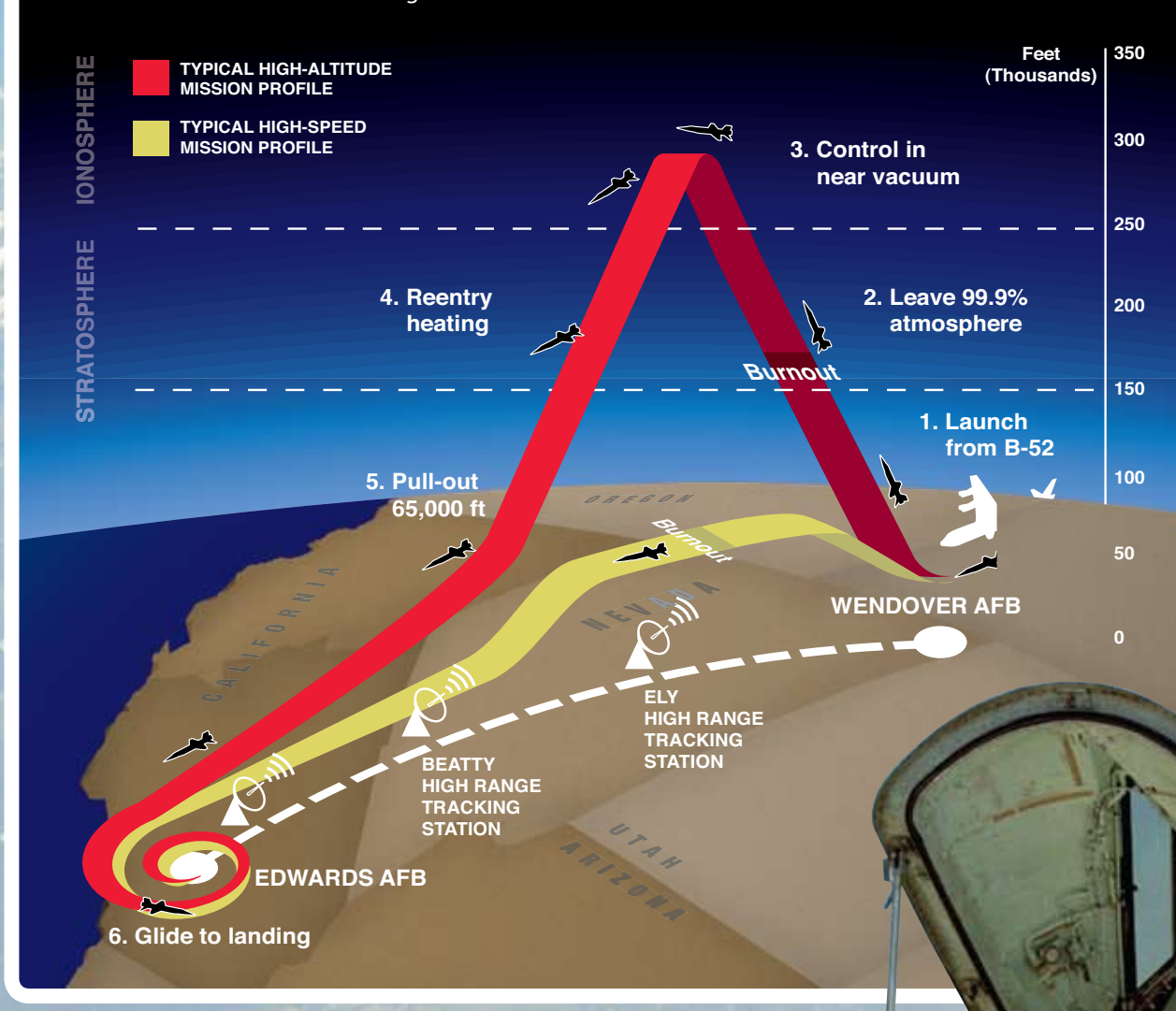


FLIGHTS OF DISCOVERY

It was all about acceleration. The B-52 carrier aircraft traveled at 500 miles per hour and 45,000 feet when the X-15 pilot hit the launch switch. A few seconds of freefall followed, and then the earth-shattering powerful 52,000-pound XL9R99 rocket engine ignited and catapulted the 33,000-pound X-15 toward Mach 5.

The heart rate of an X-15 pilot ranged from 145 to 185 beats per minute as the adrenaline surged. Chest-to-back acceleration was 2-g up to 4-g. All engine shutdown after nearly 90 seconds must be honored. The helmet against a headrest in front of him for the 2-g of immediate deceleration. The rest of the 8- to 12-minute flight continued without rocket power.

On high-altitude missions, the pilot experienced microgravity ("zero-g") for nearly 2 minutes as the X-15 often soared past 200,000 feet. After grasping the curvature of Earth, the pilot experienced 5- to 6-g during reentry. On high-speed missions, the X-15 reached an altitude of 100,000 feet, which heated the skin of the airplane until it glowed nearly red-hot. It could also accelerate from Mach 5 to Mach in an eye-waterring six seconds.



X-15 ACHIEVEMENTS

THE X-15'S LEGACY IS QUANTIFIABLE NOT JUST IN TERMS OF SPEED OR ALTITUDE ACHIEVEMENTS, BUT ALSO IN TERMS OF WHAT IT TAUGHT NASA AND THE AMERICAN PUBLIC ABOUT THE FUTURE POSSIBILITIES OF HYPERSONIC FLIGHT. THESE ACHIEVEMENTS INCLUDE:

- Development of the first practical full-pressure suit for pilot protection in space
- First application of hypersonic theory and wind tunnel work to an actual flight vehicle
- Development of computer-based simulation as an engineering and flight-planning tool
- Development of a servo-actuated ball nose flow direction sensor for accurate measurement of angle of attack and sideslip angle at supersonic and hypersonic speeds
- Development of inertial flight data systems capable of functioning in high dynamic pressure and space environments
- Demonstration of a pilot's ability to control a rocket-boosted aerospace vehicle through atmospheric exit

HEROES OF THE HYPERSONIC

A total of 12 test pilots from NASA, the U.S. Air Force, the U.S. Navy and North American Aviation flew the X-15.

<p>A. Scott Crossfield North American Aviation's Crossfield was the first X-15 pilot on March 26, 1960. He piloted the first free flight on June 8, 1959, and the first powered flight on September 17. He completed 1 glide and 13 powered flights, reaching a maximum speed of Mach 2.97 (1,960 mph). In July 1962, he was a joint recipient of the Collier Trophy, which was presented by President John F. Kennedy.</p>	<p>Joseph A. Walker Walker made the first X-15 flight by a NASA pilot on March 26, 1960. He flew the airplane 25 times and made the highest flight (354,200 ft) of the program on August 22, 1963. He also flew the fastest flight—4,520 mph of the basic X-15 configuration. In July 1962, he was a joint recipient of the Collier Trophy, which was presented by President John F. Kennedy.</p>	<p>Robert M. White Air Force test pilot White made 15 flights with X-15 between April 13, 1960, and December 14, 1962. White was the first pilot to fly any aircraft faster than Mach 4, and he, as well as the first to fly above 200,000 and 300,000 feet. He set the only official world record of the X-15 program when he flew to 314,750 feet on July 17, 1962. A Fédération Aéronautique Internationale altitude record that still stands.</p>	<p>Forrest S. Petersen Petersen was the only Navy pilot to fly the X-15. He made five flights in the aircraft at speeds of up to Mach 5.30 (3,600 mph). Petersen had the dubious distinction of making the program's first uprange emergency landing on January 10, 1962, at Mud Lake. In July 1962, he was a joint recipient of the Collier Trophy, which was presented by President John F. Kennedy.</p>	<p>John B. McKay "Jack" McKay made 29 X-15 flights, reaching Mach 5.65 on August 26, 1964, and a peak altitude of 295,000 feet on September 28, 1963. McKay was seriously injured on November 9, 1962, during an emergency landing at Mud Lake, but he recovered and flew 22 more X-15 flights. The airplane he crashed was rebuilt into the advanced X-15A-2.</p>	<p>Robert A. Rushworth Rushworth flew the X-15 more times than any other pilot, logging 34 flights in total, including 27 with the interim XL9R11 engines. During these flights, he achieved Mach 6.06 (4,018 mph) and 285,000 feet altitude. He was the second Air Force X-15 pilot (after Bob White) to attain an astronaut rating by flying the X-15 and was the first pilot to fly the advanced X-15A-2.</p>	<p>Neil A. Armstrong A name synonymous with aeronautical achievement, Armstrong was actively engaged in both piloting and engineering aspects of the X-15. As a NASA test pilot, he completed seven X-15 flights, including the first flight of the X-15's adaptive flight control system. Armstrong would ensure his place in history on July 20, 1969, when he became the first human to land on the moon during the Apollo 11 mission.</p>	<p>Joe H. Engle Engle completed 16 flights in the X-15, exceeding Mach 5 on 10 of those flights. In June 1965, he climbed to an altitude of 280,000 feet, thereby earning his Air Force astronaut rating long before he joined the NASA Astronaut Corps. He accumulated the last of his 224 hours in space when he commanded the Space Shuttle Discovery during STS-5111 in 1985.</p>	<p>Milton O. Thompson Thompson began flying X-15 on October 29, 1963, and went on to complete 14 flights during the next 2 years, reaching Mach 5.49 (3,712 mph) and a peak altitude of 214,100 feet. In 1962, Thompson was selected as the sole NASA test pilot for the X-20 Dyna-Soar, the first viable reusable space plane in history. His program was canceled prior to its first flight.</p>	<p>William J. Knight "Pete" Knight flew the fastest flight of the program on October 3, 1967, when he advanced X-15A-2 to reach Mach 6.70 (4,520 mph). He also had more than his share of eventful flights. For instance, while climbing through 107,000 feet at Mach 4.17 on June 29, 1967, he suffered a total electrical failure. Knight calmly glided to a safe emergency landing.</p>	<p>William H. Dana Bill Dana was at the controls of the 199th and final flight. During his 16th mission, he achieved a speed of 3,897 miles per hour and a peak altitude of 306,900 feet—slightly above 58 miles. Along with three other NASA X-15 pilots, he was later awarded astronaut wings for his achievement. For his service as a flight research pilot, he received NASA's Distinguished Service Medal in 1997.</p>	<p>Michael J. Adams Adams flew the X-15 seven times. He reached a maximum speed of Mach 5.94 and a maximum altitude of 266,000 feet, which qualified him as an Air Force astronaut. On November 16, 1967, Adams was at the controls when the third X-15 entered a hypersonic spin and broke up at approximately 62,000 feet. Adams was killed: the X-15-3 destroyed.</p>
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X-15 PROGRAM MILESTONES
www.nasa.gov

1952 The National Advisory Committee on Aeronautics, NACA, increases research into flight up to Mach 10 and to altitudes of 12 to 50 miles.

1954 NACA teams establish the characteristics of a new research airplane, which subsequently becomes the X-15.

1955 North American Aviation is chosen to develop three X-15 research airplanes.

1956 Reaction Motors is awarded contract to develop the XL9R99 rocket engine.

1957 Construction begins of the X-15 airplanes.

1958 Work on the X-15-1 is completed.

1959 First captive flight of the X-15 mated to the B-52.

1959 First glide flight of the X-15-1.

1960 First flight using the XL9R99 engine.

1961 First flight above Mach 5.

1961 First flight above 200,000 feet.

1961 First flight above Mach 6.

1961 First flight above 300,000 feet.

1963 First civilian flight above 50 miles.

1963 Unofficial world altitude record of 354,200 feet set on August 22.

1967 Unofficial world speed record of Mach 6.70 (4,520 mph) set on October 3.

1968 The final flight, piloted by Bill Dana, takes place on October 24.