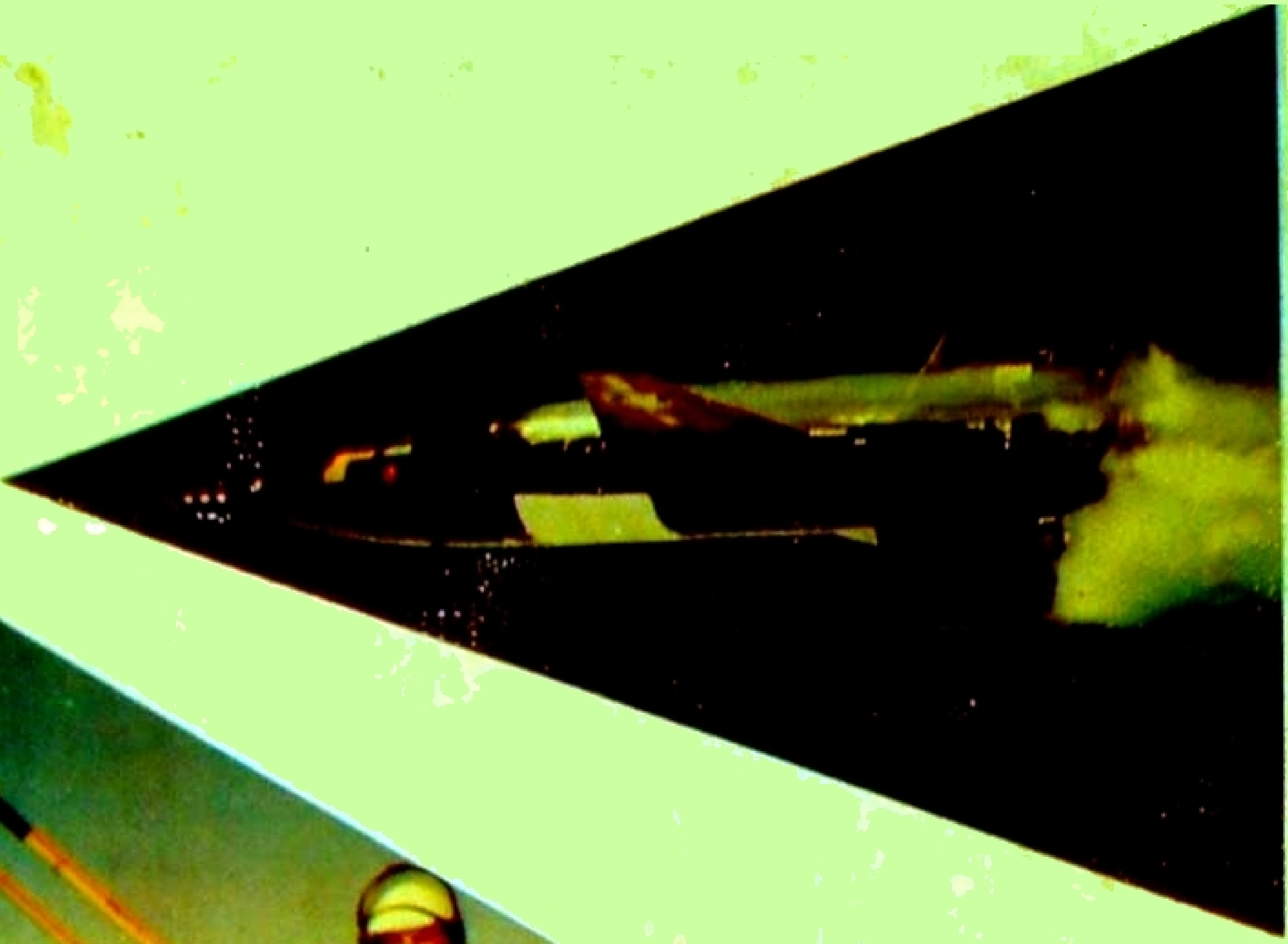
SPACE SHIP

THE STORY OF THE X-15

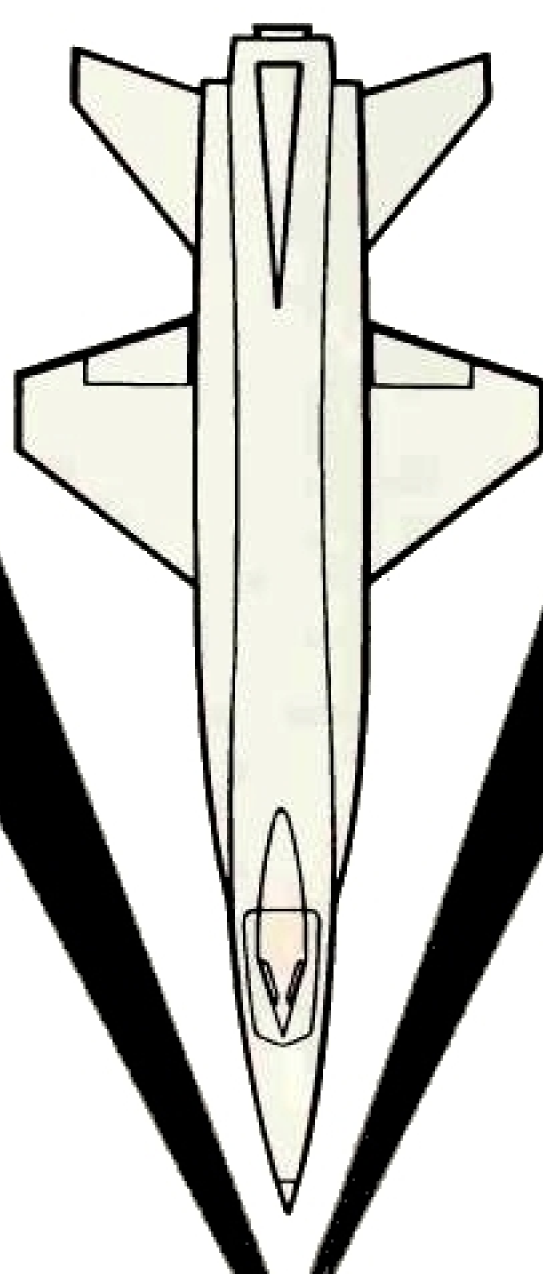


by
IRWIN
STAMBLER

SPACE SHIP

THE STORY OF THE X-15

By Irwin Stambler



Published 1961 by Irwin Stambler

Published simultaneously in the Dominion
of Canada by Longmans, Green and Company,
Toronto

Library of Congress Catalog Card Number: 61-9656

1157514

ACKNOWLEDGMENTS

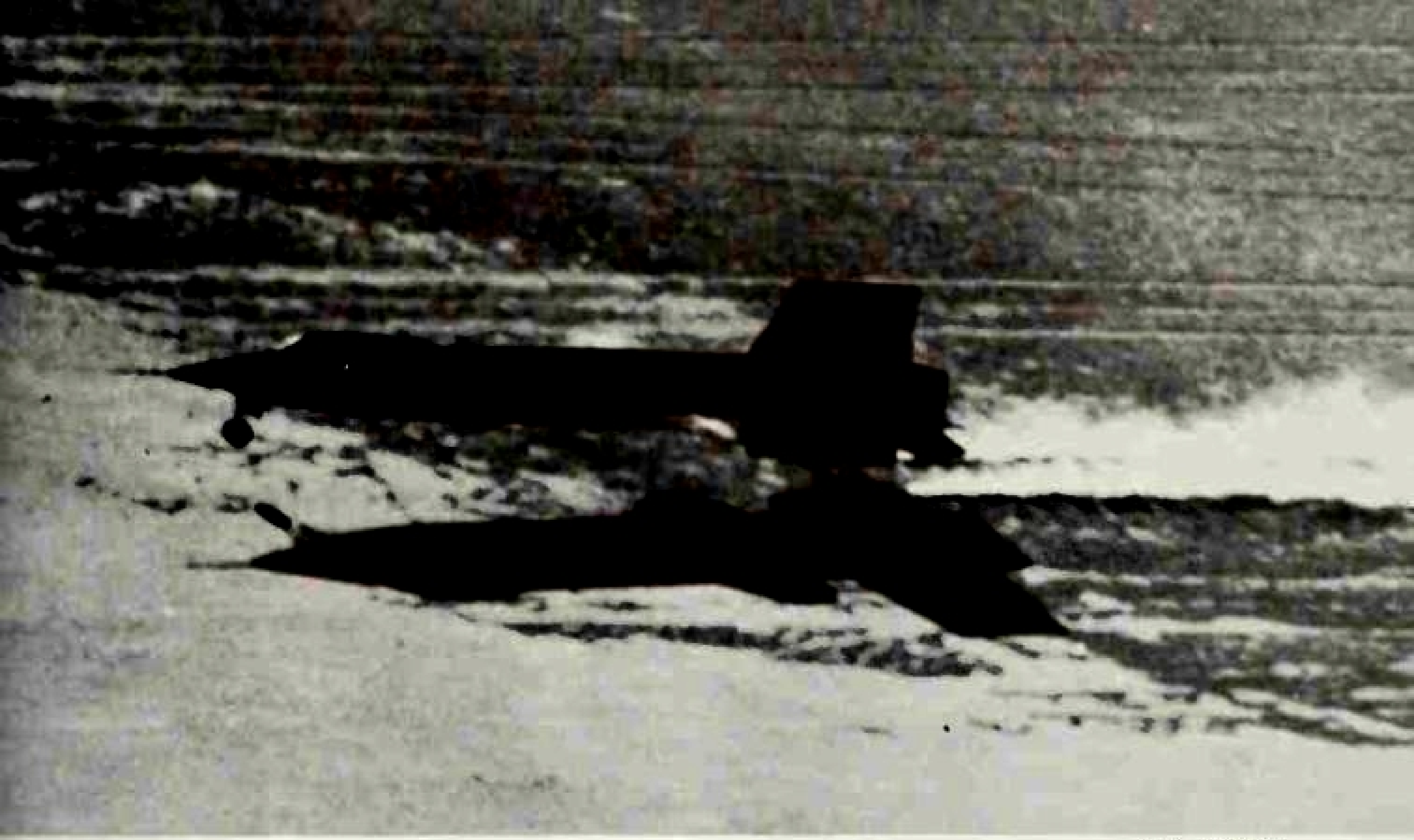
It has always been a thrill for me to discuss the width and breadth of the X-15 studies — and their implications for future space travel — with those actively and intimately concerned with the series. In the past, most of my interest has been centered on the engineering design of the plane and I welcomed the chance this book has given me to discuss the exciting human side of the picture. In this regard, I would like to warmly thank Major White, Joe Walker, Scott Crossfield and others concerned with the program for graciously devoting some of their time to discussing with me the events involved.

For their aid and assistance, I would like also to thank Major Ruth Dudley and her associates at USAF Public Information Office, Lynn Manley and Matt Portz of NASA, Don Ramsey and Gordon Gray of North American Aviation, and the public relations staff of The Garrett Corporation. Besides these individuals and firms, I would also like to acknowledge the co-operation of the following firms and organizations: U. S. Navy Public Information Office, Thiokol Chemical Company, Nortronics Division of Northrop Corporation, and General Electric Company. I would also like to acknowledge the provision of the jacket plates by the AiResearch Manufacturing Company, Division of The Garret Corporation.

My dedication of this book is a threefold one: to my mother, Mrs. Bess Stambler; to Randy Hawthorne, Bert Kirchner and the rest of the gang at *Space/Aeronautics* magazine, whose conscientious efforts in years past and present to provide engineers and scientists with needed technical data have helped make the space vehicles of today and tomorrow possible; and finally, to the young in age and in heart who will be the space travelers of tomorrow.

IRWIN STAMBLER

Torrance, Calif.
November 1960



U. S. Air Force

THE BLACK BEAUTY — the NASA-USAF-Navy manned spacecraft — glides smoothly in for a landing after another trip probing the edges of the earth's atmosphere and the beginning of the void of space. Soon the man behind the controls will step from the close quarters of the craft's cockpit to report another "mission accomplished" on the road to exploration of the far reaches of the universe. But behind the seemingly effortless performance of man and ship lie many thousands of hours of toil and preparation.

CONGRATULATIONS FROM THE FASTEST TO THE HIGHEST.

This was the message that crackled across the telegraph wires from Washington, Pennsylvania, to Edwards Air Force Base, California, on August 12, 1960. The sender was Joseph Walker, test pilot for the National Aeronautics and Space Administration (NASA), who had returned to his home town of Washington, Pennsylvania, to help celebrate its hundredth anniversary. Just a little over a week before, he had flown the first manned spacecraft, the X-15, to Mach 3.31 or 2,443 mph — faster than any man had ever flown before. The man to whom the telegram was addressed was Major Robert White of the U. S. Air Force who, on that day, had taken the same plane to an altitude of 136,500 feet, higher than man had gone before.

The incident is typical of the spirit of the little group of men pioneering the way to travel beyond the earth. The sat-

North American Aviation

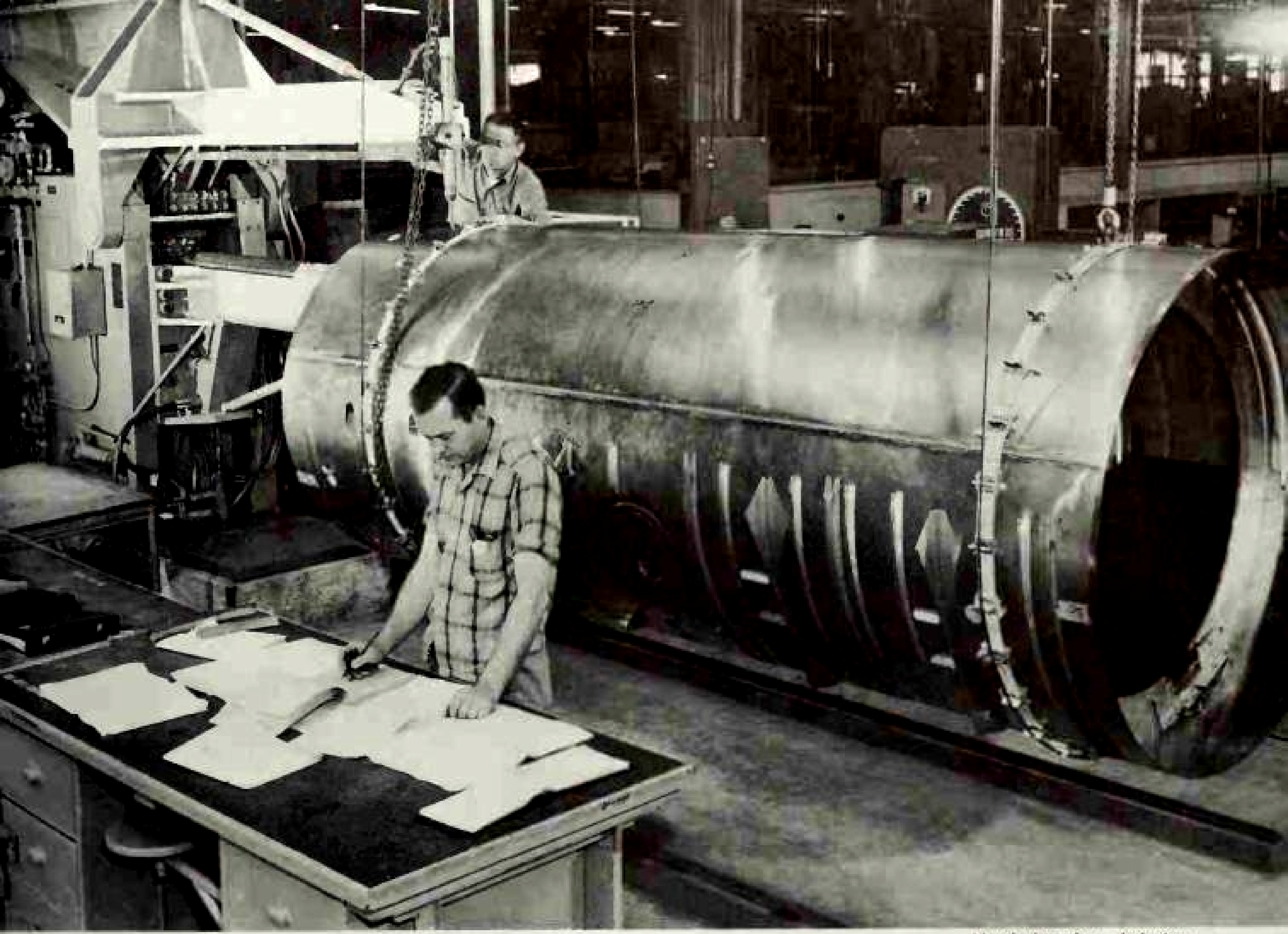
TURNING BACK the clock to 1955, the X-15 had emerged from the drawing boards of hundreds of engineers as a whole series of detailed drawings. The first step in the process toward a completed, operating airplane was building of the "mock-up."

The mock-up, shown being put together in the shops of North American Aviation, is a wooden test model of the plane used to make sure all the parts will go together properly. Sample control and accessory systems are installed in this scale model to insure they will fit and work properly.

North American Aviation

ellites and rockets probing the far-out realms of space are important to this goal, but they are only a first step. The men who fly the X-15 feel there is little use in knowing about space unless man himself can follow to see the new wonders with his own eyes. And this is the excitement of the X-15 program. It is providing the knowledge that will allow the scientists and engineers to combine maneuverable, manned vehicles with the raw power of missile engines. This will finally allow human passengers to leave the confines of Earth for Mars, Venus and points beyond and still successfully return to the friendly surface of their home planet.

There are eight members of the corps of pilots who are making the X-15 program work. Besides Walker and Major White, it includes North American Aviation (NAA) chief engineering pilot Scott



North American Aviation

STRUCTURE of the X-15 is far different from the conventional aluminum-type design used in the past. A special high-temperature material, nickel-base Inconel X, made by the International Nickel Co., is used for all exterior surfaces with much of the interior sections made of titanium alloy. The parts are also mostly joined together by welding, instead of the riveted assembly used in the past. An example is this large Inconel fuselage section shown being Heliarc seam-welded at North American's International Airport (Los Angeles) assembly plant. Three complete X-15 planes were ordered from North American by NASA.

Crossfield, NAA back-up pilot Alvin S. White, Navy Lt. Commander Forrest Petersen, NASA pilots John McKay and Neil Armstrong, and U. S. Air Force Captain Robert Rushworth. These men come from a wide variety of backgrounds, but all are united by the same desire to pioneer.

What makes a man qualified for such rigorous service? Many things of course: education, a certain type of personality, coolness under dangerous conditions, quick and accurate reactions, love of flying, and, of course, a long apprenticeship in the ways of the air.

For Scott Crossfield, the first man to fly the X-15, this apprenticeship started at a very early age. "Almost from the time I could walk, I wanted to fly," Scott recalls. At six years of age he took his first flight with a barnstorming friend of his father's in Los Angeles. (Scott was

North American Aviation

THE MAN, the other key element in the scheme, simultaneously started his long, arduous task of self-education. The first pilot chosen by North American to prove out the X-15 before delivery to NASA was Scott Crossfield. He is shown here testing out an advanced flight suit under the intense glare of dozens of heat lamps. As Scott pursued his training, he was soon joined by other pilot-designees of the Air Force, NASA and the Navy.

U. S. Air Force

RIGHT ALONG with Crossfield, the other pilots selected by the services and NASA went through rigorous pre-flight test routines. While Crossfield's job was to prove out the X-15's flyability, it was to be the job of such pilots as the Air Force's Major Robert White, shown here undergoing suit pressurization tests, to take the plane to the edges of space 100 miles up and to speeds of over 4,000 miles per hour. The suit Major White is wearing has far more capability than for X-15 flight, for, potentially, a suit such as this would permit a man to move around safely on the nearly airless surface of the moon.

born in Berkeley, California, in 1921, but his family moved to Los Angeles a short time after his birth.) By the time Scott was twelve, he had taken his first flying lessons from Vaughn McNulty, manager of the Wilmington, California, airport. Scott, a newsboy, paid for the lessons with free delivery of the Long Beach *Press Telegram*. "From then on," he says, "I was just about an 'airport bum,' hanging around airports and flying any planes I could. Some of them were the Curtiss Robin, Monocoach, Travelair, and Waco. I still remember staying up all night for four nights in a row in 1933 to watch the Bendix Trophy takeoffs at three in the morning from Mines Field. Then it was just a grass patch, but now it's Los Angeles International Airport."

As for Bob White, his introduction to flying was quite different. "I can't re-


U. S. Air Force

AN INTERESTING commentary on the type of men needed to probe the edges of space is that all the X-15 pilots are family men (as are the Mercury Astronauts). All are married with at least two children. Record holder of the group is John B. McKay of NASA with six children, closely followed by Scott Crossfield with five. Here Major White, who has three children, two girls and a boy, relaxes with his six-year-old son, Gregory, after his record altitude flight of 136,500 ft. on August 12, 1960.

member any particular time when I first knew I had to fly. I did pretty much the same things any boy would do — built model airplanes, read aviation magazines — but even when I was almost through with high school, I didn't know exactly what I wanted to do." The turning point in Major White's life was World War II. A native-born New Yorker, he was a seventeen-year-old high school senior at Samuel Gompers in New York City when the attack on Pearl Harbor occurred. He enlisted in the Air Corps in 1942 and by 1944 was a P-51 pilot with the 355th Fighter Group stationed near Cambridge, England. He completed 52 combat missions before being shot down and interned in Germany in 1945. He holds the Air Medal with seven Oak Leaf clusters.

Joe Walker, on the other hand, became interested in flying watching airliners passing over his home in Washington,

NASA

MANY YEARS of flight experience in ad-vanced aircraft were a must for those chose[n] to fly the first manned space craft. Here Jo[e] Walker of NASA emerges from the cockpi[t] of an earlier rocket test vehicle, the Be[ll] X-1E. During flight research with a previou[s] version of this craft, the X-1A, Walker wo[n] the NACA Exceptional Service Medal fo[r] fighting his way to safety after an explosio[n] rocked the plane during a flight in 1956. Jo[e] was appointed to the X-15 program in it[s] early development stages and helped pro-vide many pointers to the plane's designer[s] from his experience in simulator and centri-fuge tests.

QUICK REFLEXES are a must for X-15 pilots and this includes thinking fast both in the cockpit of the plane and before audiences of engineers and scientists. The pilots of the advanced planes must have the technical know-how to cope with the tremendous complexity of today's designs, which have thousands of feet of electrical wiring and hydraulic tubing and dozens of different internal systems. Thus the engineering test pilot often gives technical papers on aspects of his program to learned societies or student groups as Joe Walker is doing here.

NBC

Pennsylvania, where he was born on February 20, 1921. But it was not until college that he actually began flying. Here he enrolled in the government-sponsored Civilian Pilot Training program, operated under the auspices of the Civil Aeronautics Administration. Following graduation, he enlisted in the Army Air Corps and was awarded the Distinguished Flying Cross with seven Oak Leaf clusters for missions as a P-38 fighter pilot in the Mediterranean Theater.

The pattern of World War II combat flying holds for all the others in the program with the exception of the youngest, Neil Armstrong, who was born in Wapakoneta, Ohio, on August 5, 1930. But Neil did have combat service as a Naval aviator during the Korean War, flying 78 missions. Scott Crossfield served as a Navy pilot and instructor even before World War II; Captain Robert Rushworth flew 78 missions as a transport pilot in the China-Burma-India Theater;

North American Aviation

AN EARLY PHOTO of Scott Crossfield shows him during his test pilot chores with the famed North American F-100 supersonic fighter. One of the first Mach-busters built by U. S. industry on a production scale, and still a mainstay of U. S. defense forces, this plane also played a key part in early flight preparation for the X-15. "Dirty" configurations of the plane, with drag chute and speed brake open and wheels down, were used to simulate the rapid vertical descent the pilot would meet in coming in for a landing with the X-15. Each pilot made hundreds of landings with such F-100s and Lockheed F-104s to gain the proper depth perception needed to make each "one-shot" X-15 landing a success.

Commander Forrest Petersen was a Navy pilot; Alvin White flew P-51 Mustangs in Europe; and John McKay earned the Air Medal with two clusters as a Navy pilot in the Pacific Theater.

The love of flying and flying experience, however, are not nearly enough to fit a man for being the engineering test pilot of a plane such as the X-15. A critical need is a good technical background. All eight of the X-15 pilots have this know-how. Scott Crossfield, for instance, returned from the Navy after World War II to earn a Bachelor's and a Master's Degree in Aeronautical Engineering from the University of Washington at Seattle. Major White left the service to complete work on an Electrical Engineering degree from New York University before he was recalled to active duty for the Korean War. Joe Walker received a degree in Physics from Washington and Jefferson

Republic Aviation

IT WAS IN the F-105B Republic fighter-bomber, such as the one shown here, that Major White successfully overcame an inflight structural failure at Mach 1.5 and brought the plane back for a normal landing. Such experience was invaluable in preparing White for his future role in the X-15 program.

College before he left for the service. And similarly, all the other pilots hold one or more science or engineering degrees.

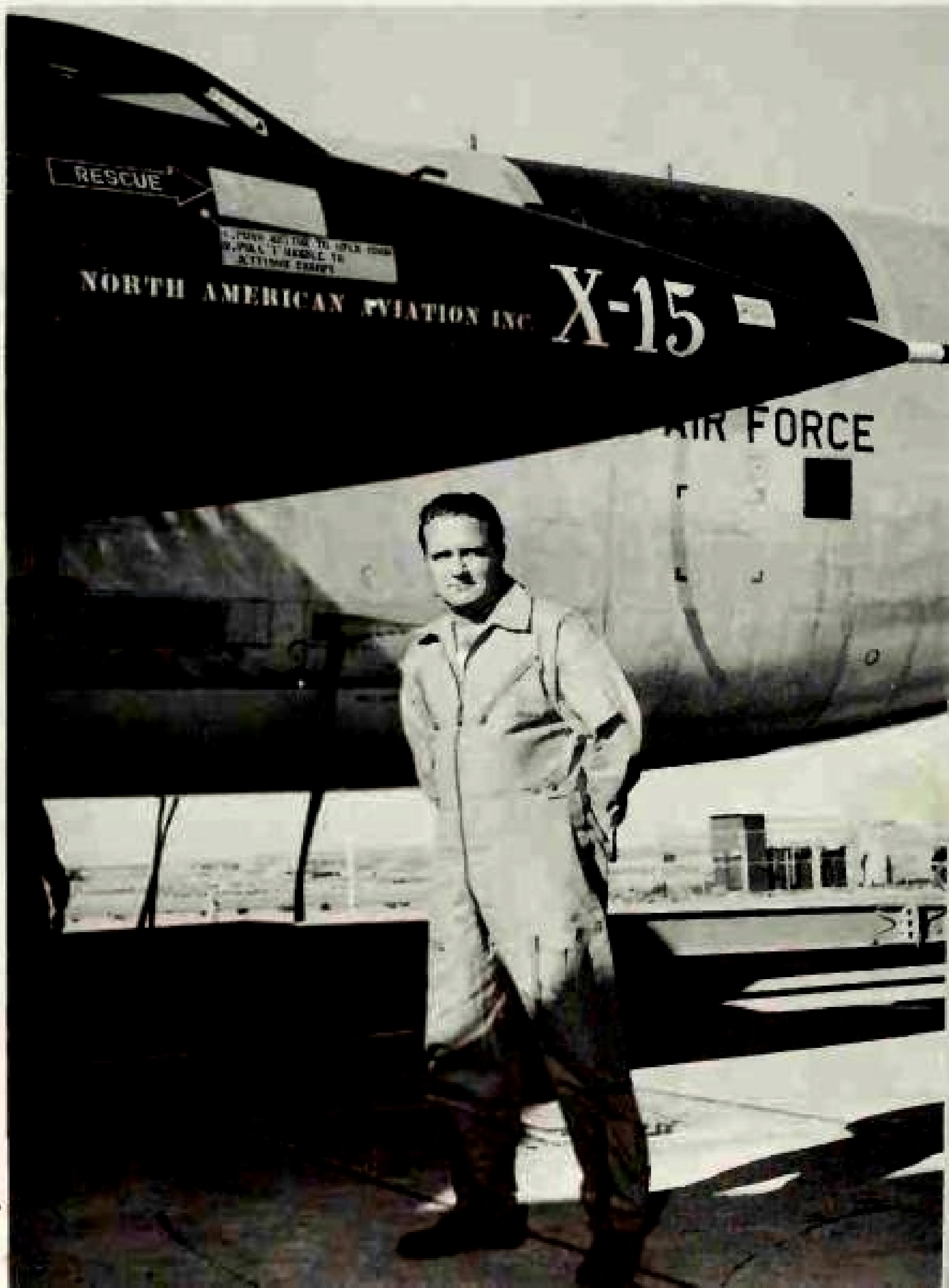
This points up the world of difference between the "seat of the pants" test flying of the days of aviation's infancy and the highly complex world of today's Space Age. The test pilot today is handling an extremely powerful, infinitely delicate machine and his job is not just to fly it, but also to understand the many "bugs" that can occur in untried vehicles. One moment something can go wrong with an auxiliary power unit that supplies power to run the craft's cooling system; another moment the flicker of a gauge on the instrument panel can show that something is going wrong with the thunderous rocket engines. The engineering pilot must be able to correct for these things on the spur of the moment. Even more impor-

LET'S MEET the other pilots in the X-15 program. This is Captain Robert A. Rushworth, born in Madison, Maine, on October 9, 1924. After World War II service, he left the Air Corps to earn a Mechanical Engineering degree from the University of Maine in 1951. After being recalled to active duty with the USAF in the Korean War, Capt. Rushworth decided to go to the Air Force's Experimental Flight Test Pilot School at Edwards AFB, Calif., from which he graduated in January '57. Planes flight tested by Capt. Rushworth include the McDonnell F-101 and RF-101 fighters, Convair F-106Z interceptor and Lockheed F-104A fighter.

U. S. Air Force

NASA'S John B. McKay came to the X-15 program by way of a long list of successful flight tests with such rocket research vehicles as the Douglas D-558-I and D-588-II, Bell X-1B, X-5 and fighter designs such as the Convair F-102A and North American F-107. Virginia claims McKay as a favorite son: he was born in Portsmouth, Va., on Dec. 8, 1922, and graduated with a B.S. in Aeronautical Engineering from Virginia Polytechnic Institute in 1950. He has authored a number of technical papers, including an NASA Research Memorandum on "Aileron and Elevator Hinge Movements of the Bell X-1 Airplane Measured in Transonic Flight."

NASA



NASA

PR'DE of the Navy is Lt. Cmdr. Forrest Petersen, fourth of the group to fly the X-15. The first of the four alternate pilots to be checked out in the spacecraft, he reached Mach 2 on a flight in September 1960. Petersen was born in Holdrege, Nebraska, in 1922 and attended Nebraska University. World War II came along and he shifted to the U. S. Naval Academy at Annapolis, Md., earning his Bachelor of Science degree in 1941. Ever since then, Petersen has been a Navy pilot, graduating with honors from the Naval Test Pilot School in 1958.

tant, he must be able to sit down with engineers and tell them what happened and perhaps how this can be fixed so that the pilots of future routine air or space craft won't have these things to worry about. Many times an engineering pilot will look over the shoulder of an engineer working on a drawing of some part of an advanced plane and note something that needs correction. The engineer welcomes this, for it can save many wasted hours of testing as well as prevent accidents.

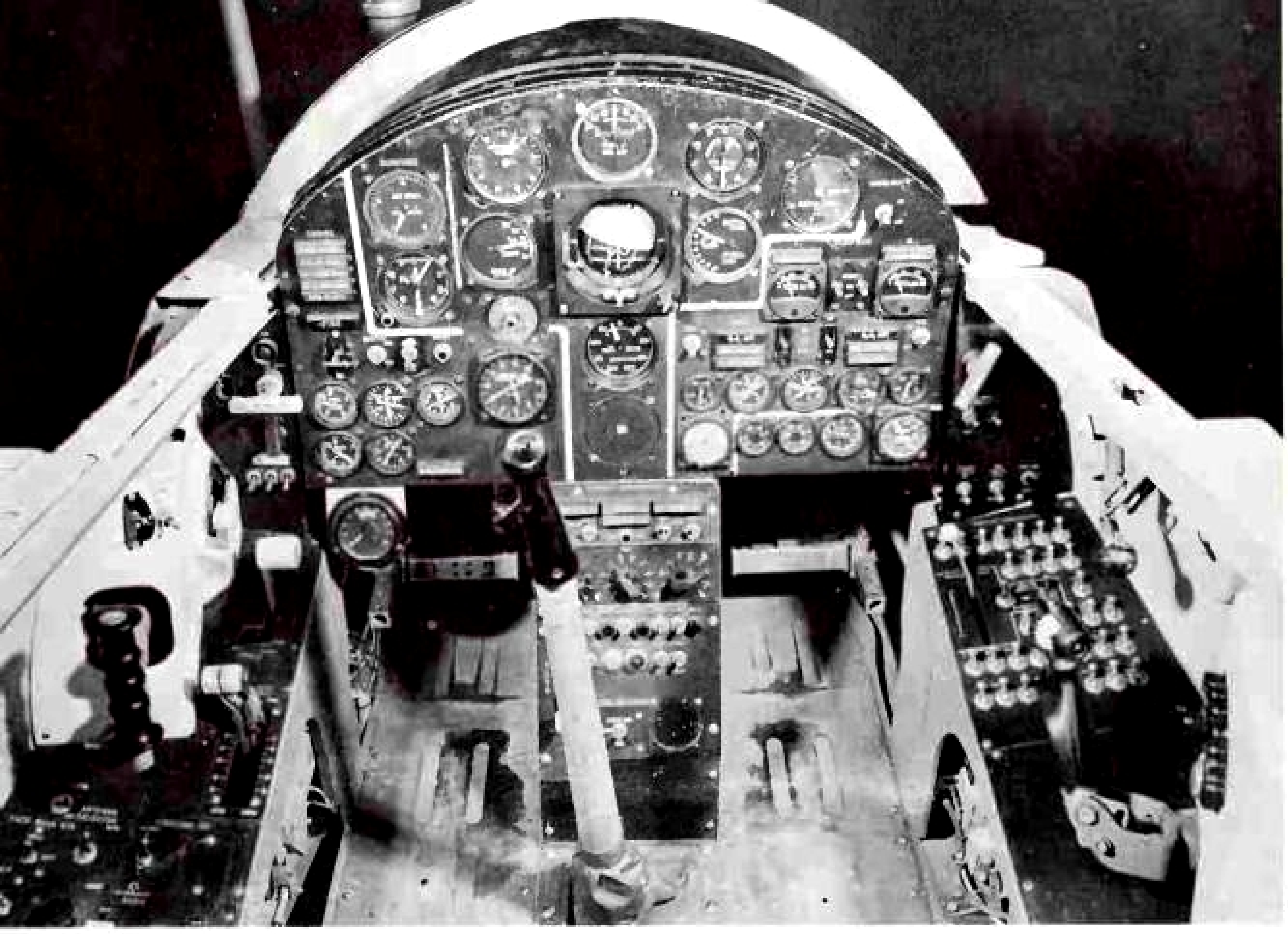
Once beyond engineering school, and with many hours of flying under their belts, these eight men, at some point along the line, found the desire within themselves to probe the edge of the unknown. Joe Walker, after his hitch overseas, returned to the United States with a desire to continue flying. Recruiters for the National Advisory Committee for

BACK-UP PILOT for North American is Alvin S. (Al) White. Born Dec. 9, 1918, in Berkeley, Calif., he is a graduate engineer from the University of California. During World War II, Al was a P-51 pilot in Europe and later served as an Air Force test pilot at Wright Patterson AFB and El Centro before joining North American in 1954. In the X-15 program, Al is mainly an understudy for Crossfield in case of emergency, but he has his work cut out for him in future North American projects, since he has been designated Chief Pilot for the B-70 Mach 3 bomber.

North American Aviation

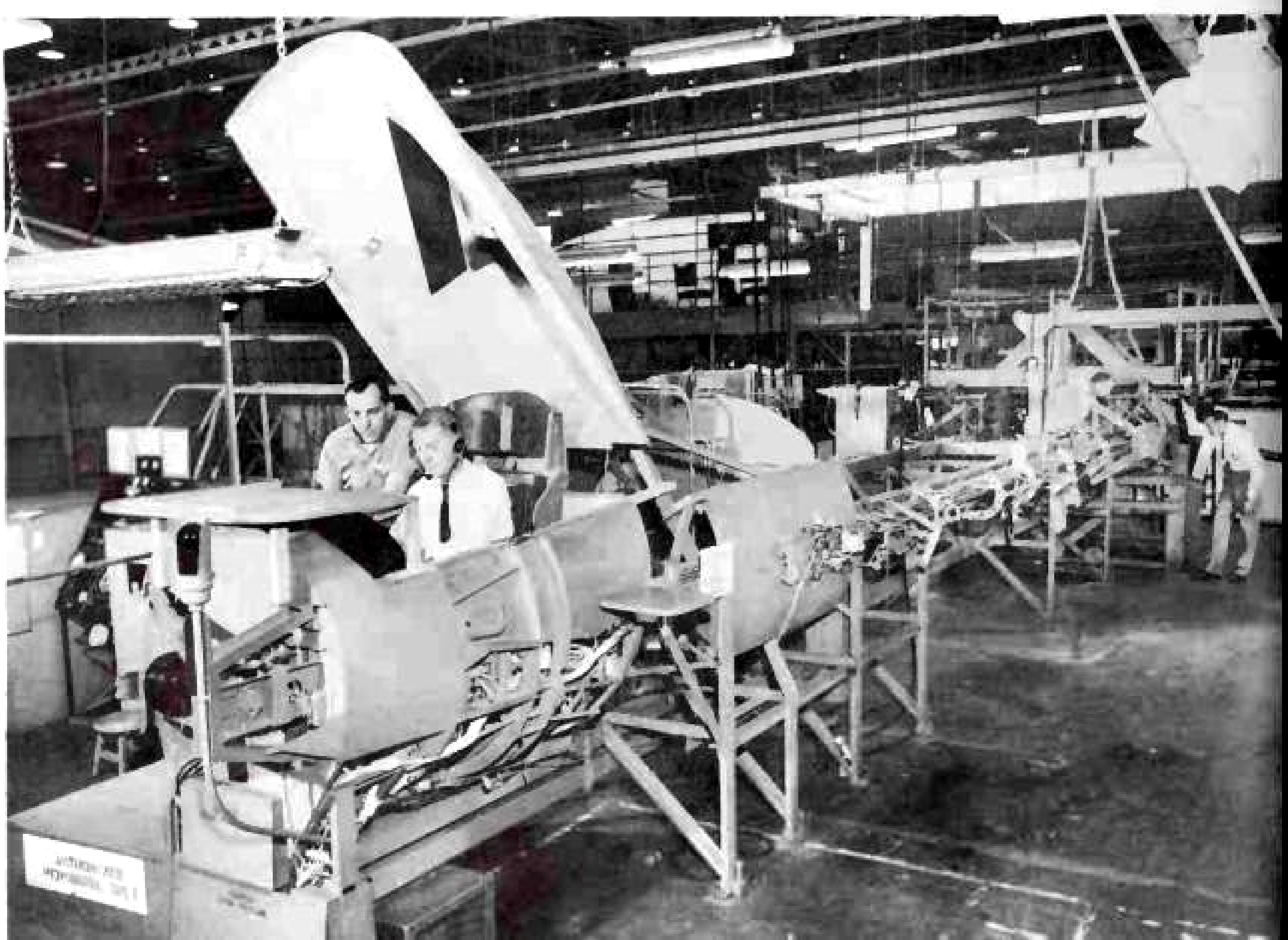
NASA

"YOUNGSTER" of the X-15 group is NASA's Neil A. Armstrong, but his experience measures up to all the others in every way. He has served as project pilot on the NAA F-100A and F-100C, McDonnell F-101, F4H and Lockheed F-104A fighters. Besides this, he has flown the X-1B, X-5 and F-102A. He has also proven his mettle in successfully completing some of the most backbreaking tests in the X-15 program, including going to a simulated altitude of 200,000 ft. in a low-pressure chamber. Armstrong is also an aeronautical engineer, having received his B.S. from Purdue in 1955.



North
American
Aviation

SIMULATOR FLIGHTS in this X-15 cockpit mock-up at North American's Inglewood plant let the pilots go through the most arduous X-15 maneuvers without ever leaving the ground. The instrument panel array shown above is exactly the same as that in the actual plane. At the right, North American engineers are shown checking the simulator out. The wires and "plumbing" run to a hookup with an electronic computer that programs exact X-15 flight patterns into the instrument panel. For hour after hour, while the X-15 was being built elsewhere in the plant, Crossfield, Walker, White and the others learned the split-second timing needed to come through unscathed when flying near the outer limits of the earth's atmosphere.



North American Aviation

THE CENTRIFUGE at the Naval Air Development Center, Johnsville, Pa., was another important "torture chamber" in pilot preparation. Inside this steel sphere, which is whirled around at the end of a 50-ft.-long arm, the pilot must successfully control simulated X-15 instruments while a force up to 1,000 lbs. literally squashes him back in his chair. In some centrifuge runs, the sphere is not only whirled around, but is rotated until the pilot is practically standing on his head.

Aeronautics (NACA) had permission to find qualified technical people and obtain their service release if they wanted to work for NACA. (Then the federal research agency for advanced aeronautical studies, NACA was the forerunner of the present NASA.) Walker agreed to work as a physicist at the Lewis Flight Propulsion Laboratory in Cleveland. Within four days after he arrived, he found that the lab was running a flight test program to study the effect of engine icing in a P-38. He rushed over to the project leader and wanted to know if they needed a test pilot. They did, and from that moment on, test flying was Joe Walker's life. About the same time, Scott Crossfield, in the state of Washington, was on the research staff of the wind tunnel at the university. But the love of flying was in his blood and he applied for a position as a test pilot at NACA's Muroc Dry Lake (California) High Speed Flight Research Station and won the job. In

The tremendous forces involved are amply demonstrated by this picture of Scott Crossfield's distorted face taken during a high-speed centrifuge run.

North American Aviation

"ANTHROMORPHS" — special dummies that exactly simulate the human body — played a major role in helping develop X-15 equipment. Some were dropped from high-flying planes to test parachute designs. Others, as this one here, were shot from a sled propelled to high-Mach speeds by solid-propellant rockets to test escape seat stabilization and pressure suit design. The striped vanes shown in this picture are attached to the pilot's escape seat so that, in case he must eject himself in an emergency, the seat will aerodynamically assume the right position for parachute extension.

North American Aviation

North American Aviation

ENGINEERING homework is all part of the day's work for X-15 pilots. Here Scott Crossfield studies drawing and reports on the plane with the engineer's trusty slide rule near at hand. Scott and the other "spacemen" helped design many important parts of the craft, particularly the lightweight space suit and its cooling equipment.

other ways, but with the same end result, the other future X-15 pilots won their spurs.

And now all of the eight started on the last lap of the journey toward space though, of course, they were all unaware of how fast modern technology would move in just a few years. Major White was USAF project pilot on such advanced craft as the North American F-86K, Northrop F-89H, Convair F-102 and Republic F-105B. Crossfield flew the Bell X-1 rocket plane, the X-4, X-5, XF-92, D-558-2, F-86 and F-100. In the D-558-2 Douglas research ship, he cracked the speed barrier with a Mach 2.01 reading in November 1953. Walker was project pilot on the Lockheed F-104, X-1E, X-3, X-5 and F-100A. The other pilots tested these and many other advanced craft. Just about every famous high-perform-

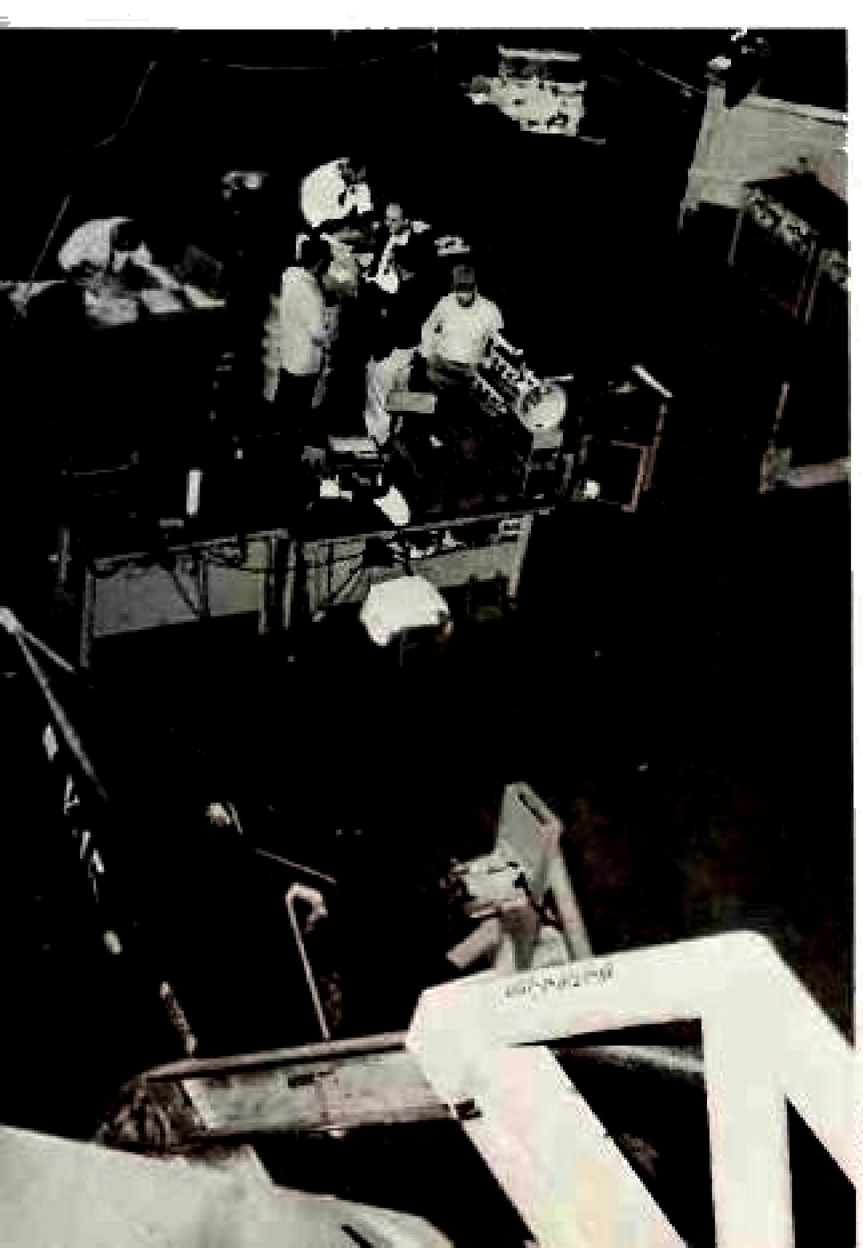
North American Aviation

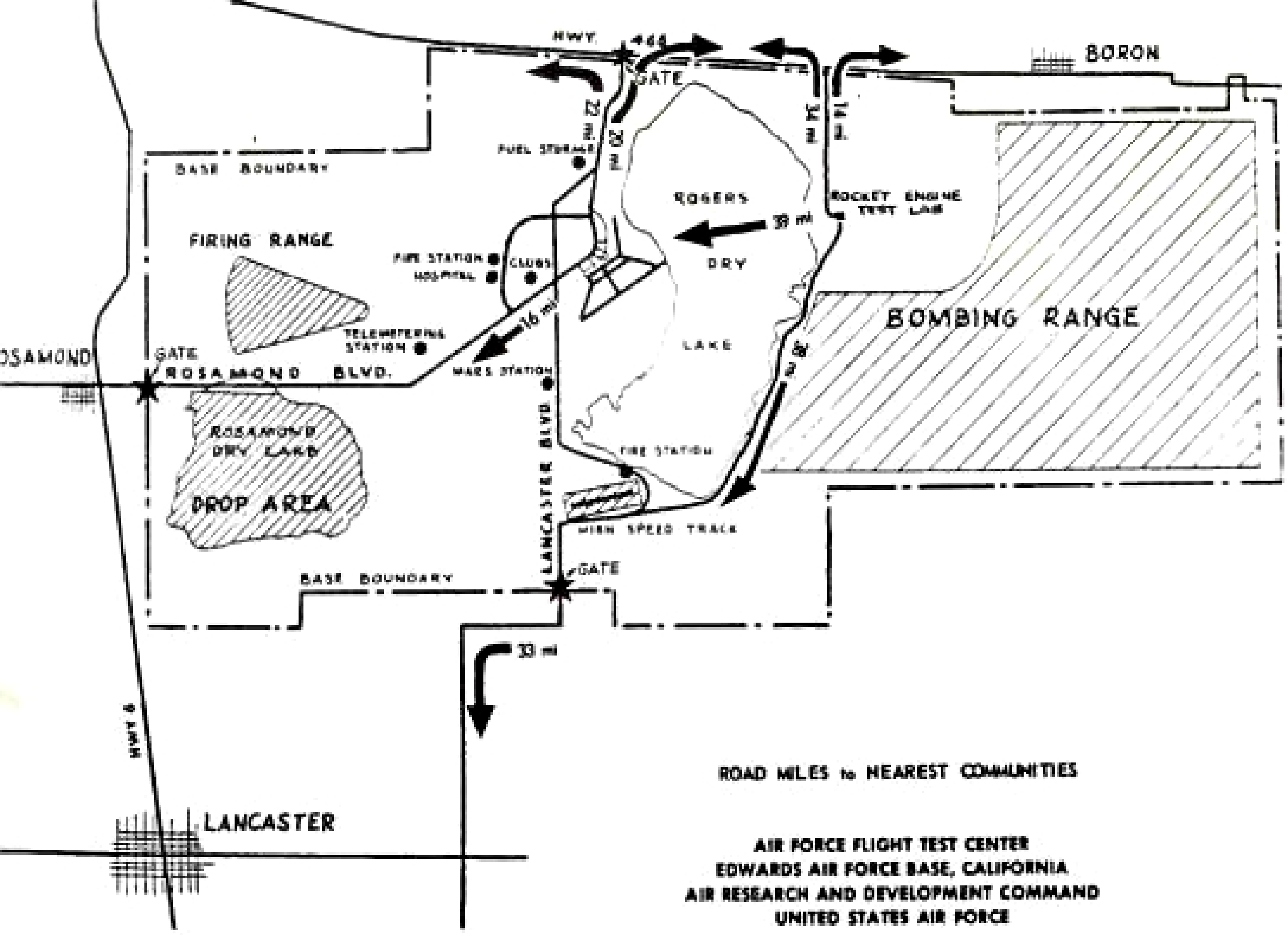
FINALLY the first X-15 is completed and now the pilots start familiarizing themselves with the actual cockpit even while the plane is still undergoing in-plant tests before rollout. Here, during such a study in the late night hours, an X-15 pilot is bathed in the glow from the indicators on the instrument panel.

ance plane of the last decade has been "wrung out" by one or the other of these pilots.

During these many flight hours, all the pilots were learning to cope swiftly and effectively with unexpected emergencies. Major White, for instance, was flying the Republic F-105 fighter-bomber in a key flight in the test program on this supersonic plane. The craft was traveling along at Mach 1.5 at 20,000 feet when Major White suddenly felt a tremor and a sharp bump that seemed to run throughout the plane. What had happened was that large pieces of the intake duct structure had broken loose and been sucked into the engine. Jet engines, of course, are very sensitive to any foreign objects sucked into them, since even small bolts or stones can batter against the engine's rotating parts and cause the engine to tear itself to pieces. This is the reason special run-

MANY TESTS await the completed X-15 before it will be ready to move "into the field." Here it is hung from the wing of the B-52 and subjected to all kinds of simulated flight loads to test its ability to maintain proper air stability while attached to the bomber. Sensitive strain gauges are located all over the plane's surfaces and lead weights fastened to different parts of its fuselage and wings. As the weights are applied, the readings from the gauges are transmitted through the wires shown on the plant floor to the banks of electrical and electronic equipment shown in the foreground. Engineers can tell by looking at this information how the plane is reacting.

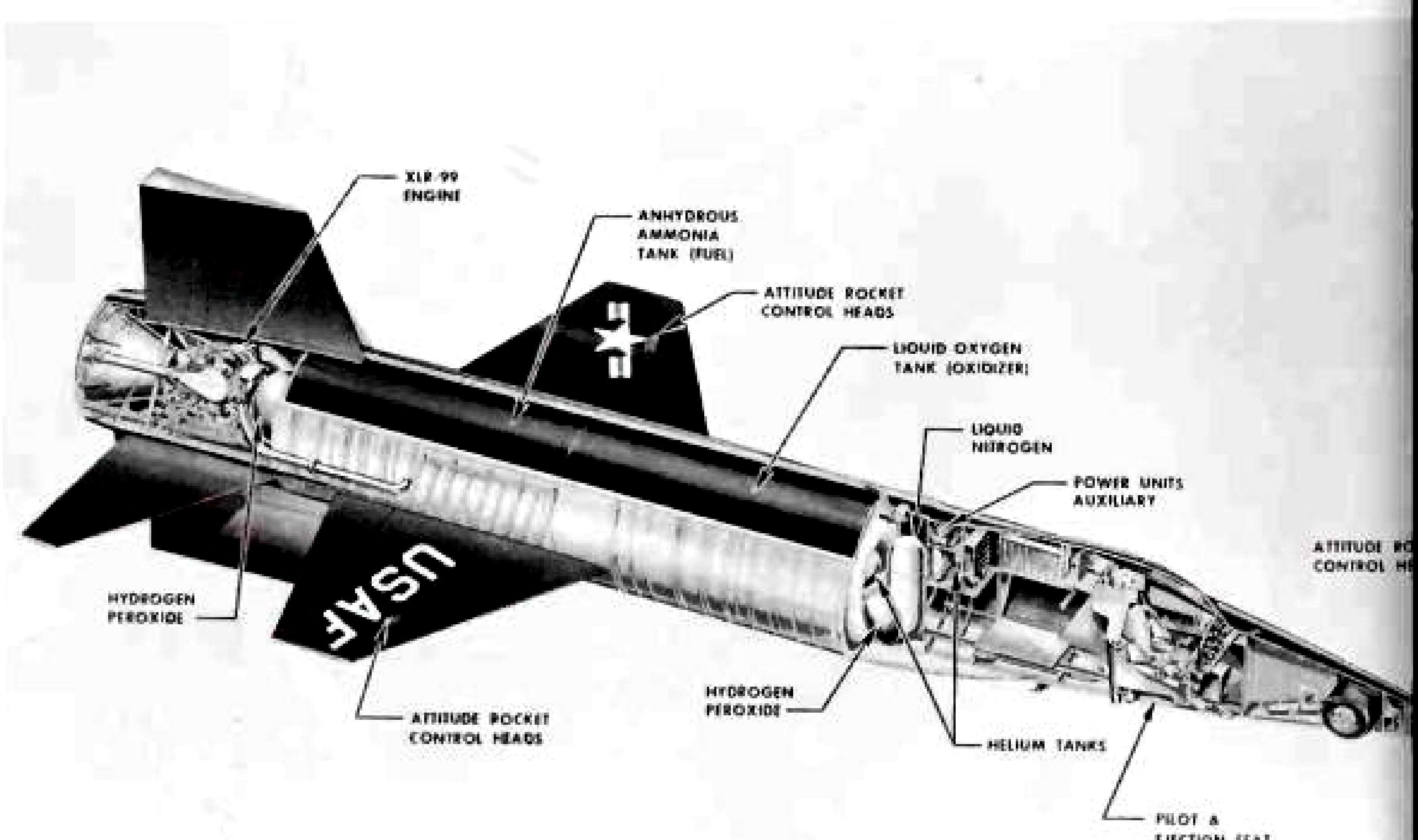




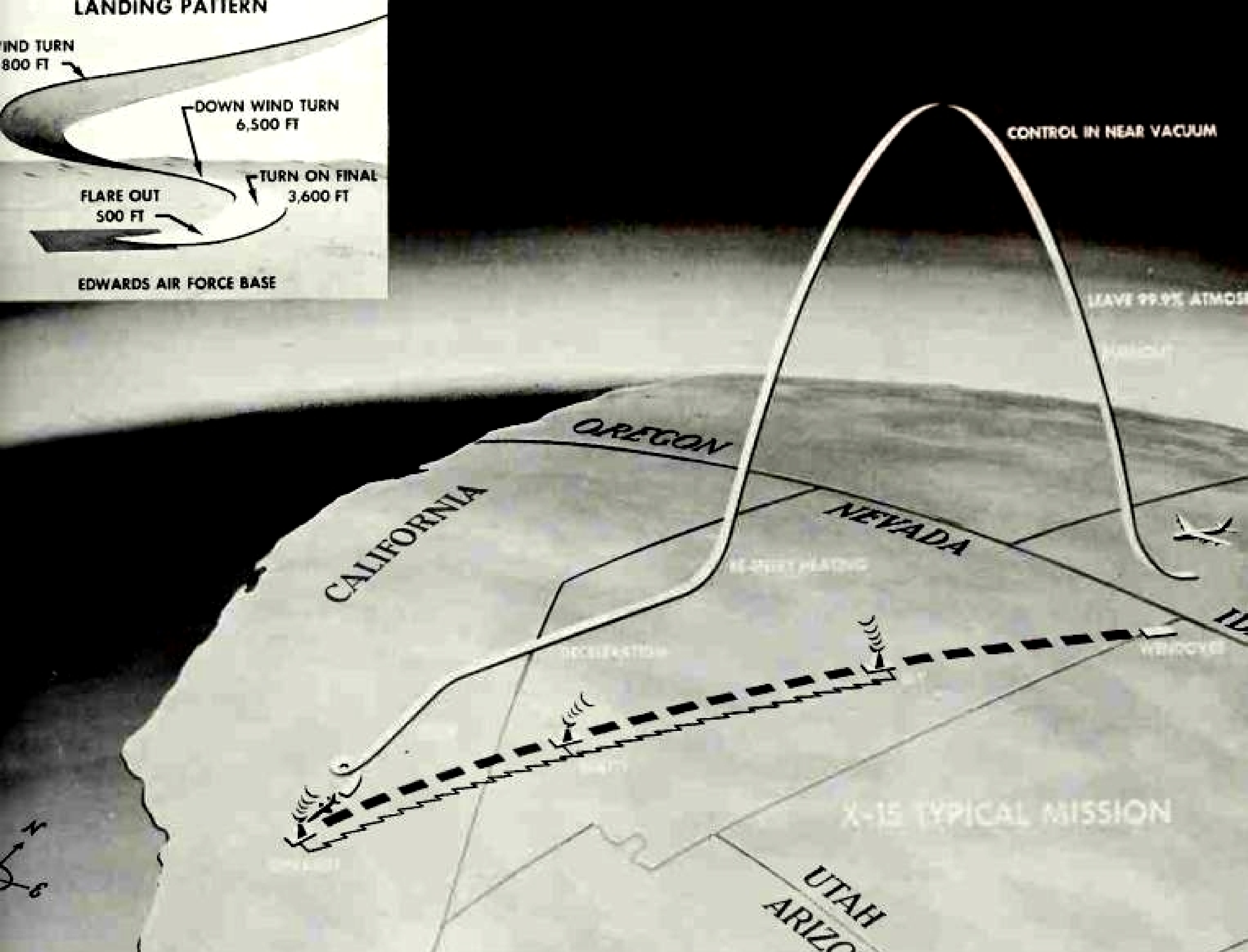
U. S. Air Force

EDWARDS AFB, about 100 miles above Los Angeles, contains two "dry lakes," Rogers and Rosamund. These are the dried-up beds of ancient lakes in the desert area that provide runways several miles long for high-performance test planes. The white, hard-packed base of Rogers is the goal of the X-15 pilots.

THIS CUTAWAY shows the main working parts of the first manned space craft. The diagram shows the latest version of the plane with a 60,000-lb. thrust Thiokol XLR-99 engine. For the 1959-60 tests, the X-15 was outfitted with smaller interim engines providing 16,000-lb. thrust. Even with these engines, the record performances of 136,500 ft. altitude and Mach 3.31 were made. The improved XLR-99 provides the "kick" to take the craft to 100 miles altitude (500,000 ft.) and Mach 5-6. The sketch shows the location of the plane's propellants, the ammonia fuel and the liquid oxygen oxidizer. Note also the liquid nitrogen tank, used in the plane's cooling system for pilot and electronic equipment.



NASA

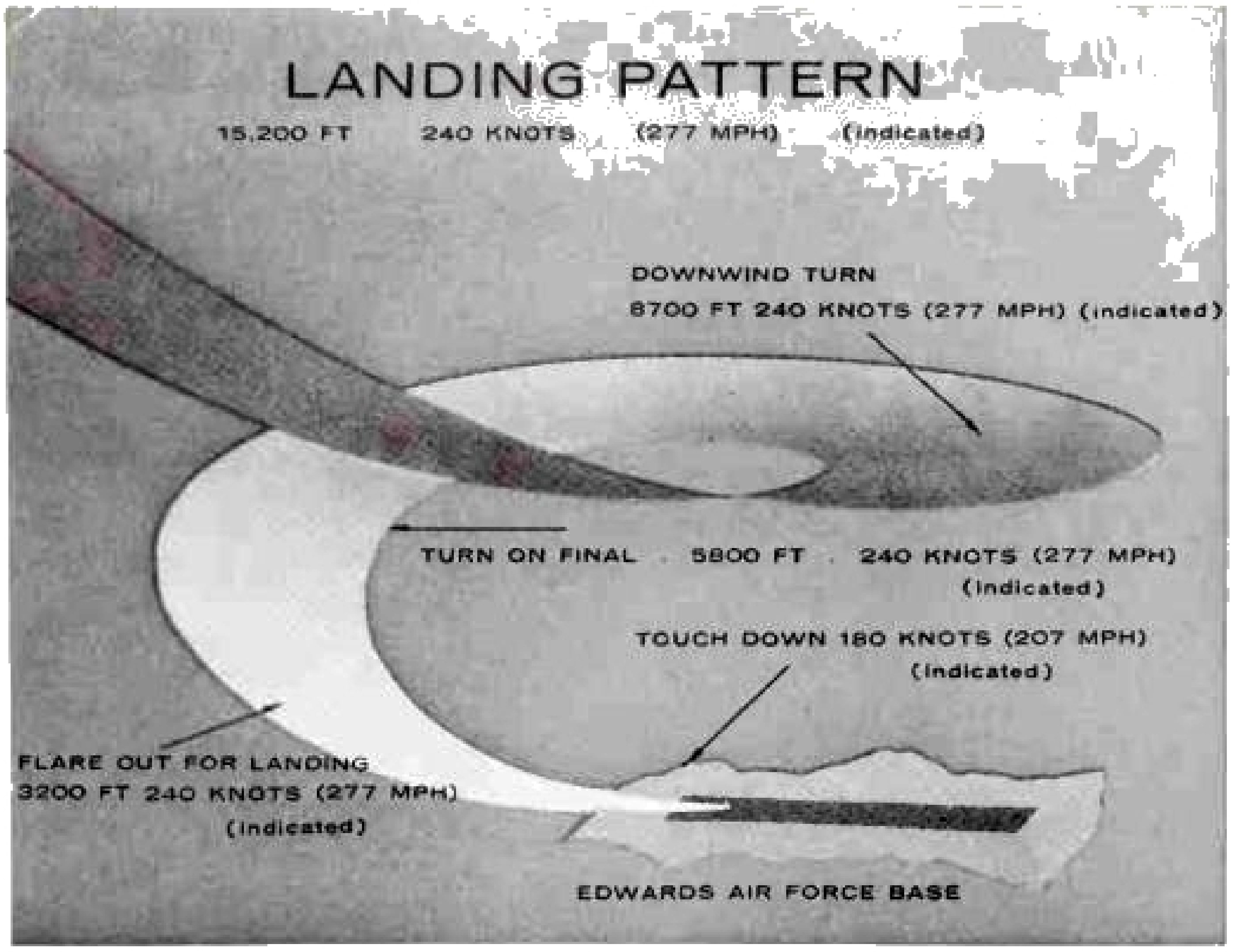


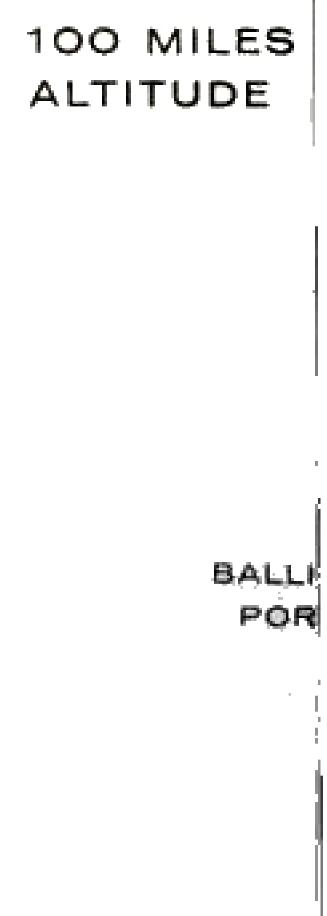
North American Aviation

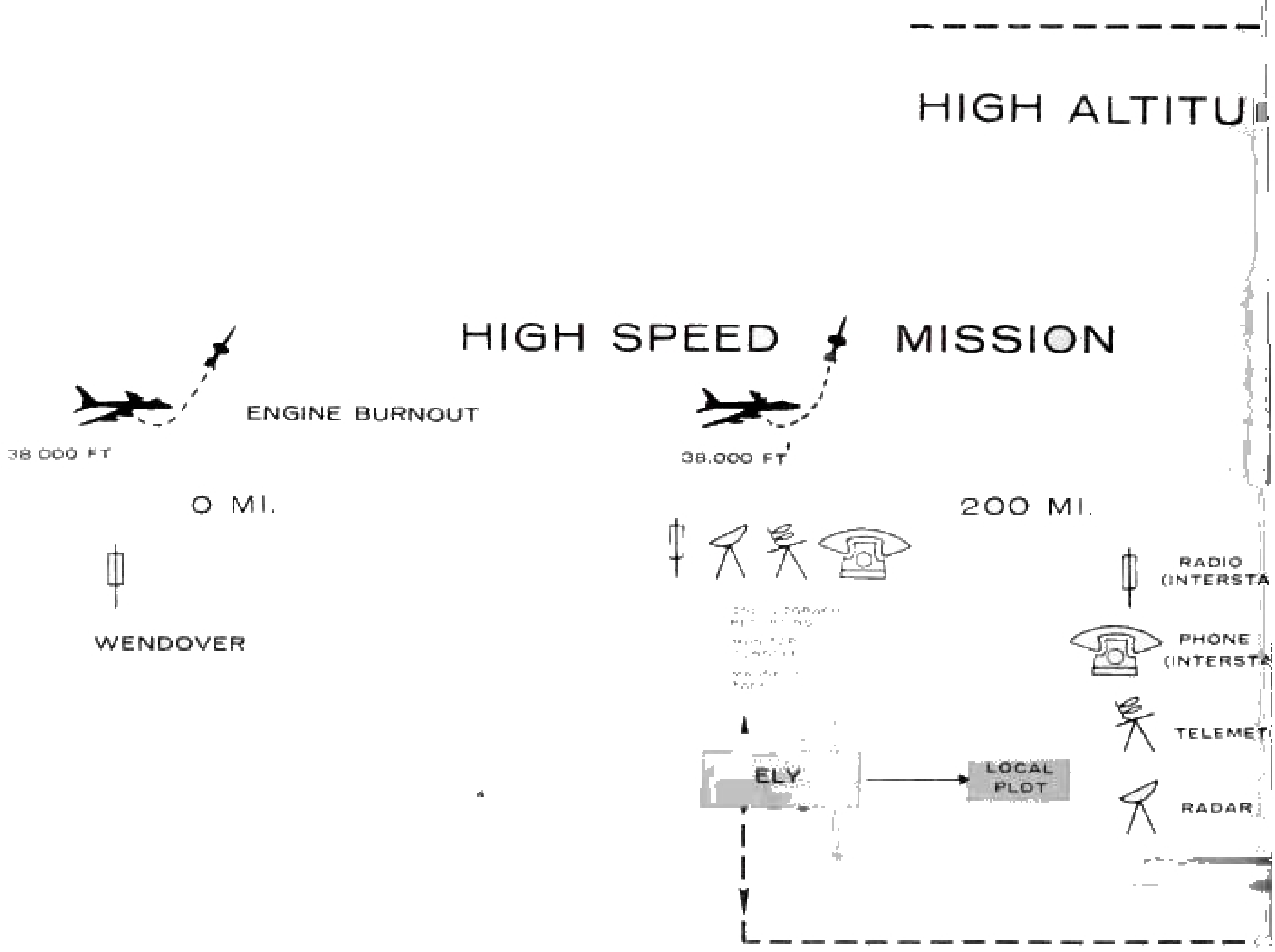
AS THE X-15 nears flight readiness, the last pieces of equipment are installed in High Range, the string of monitoring and tracking stations that marks a 485-mile flyway 50 miles wide and as high as the edge of space. As the diagram shows, High Range stretches from Wendover in the northwest corner of Utah angling in a southwesterly direction over Ely and then Beatty in the Bullfrog Hills near Nevada's western border, thence over the Mojave Desert of Southern California to the target of Rogers Dry Lake at Edwards AFB, Calif.

way sweepers are used to clean airport runways, not only on military fields but also at strips used by today's high-speed jet transports. For a moment the plane shuddered as though it would fall apart, but, almost miraculously, the structure passed through the engine without stopping it. White's many hours of dangerous flying paid off, for he continued to maintain control of the plane all through the critical few moments and was able to land it normally.

In many other cases, Major White, Joe Walker and all the other X-15 pilots ran into similar emergencies — engine flameout, mid-air explosions, jamming of a control surface — the many, many things that can go wrong with new aircraft designs. But each time their steadiness, their complete acceptance of the unusual as just part of the job, saw them through. Each hazard successfully overcome made each man readier for the X-15 assignment.



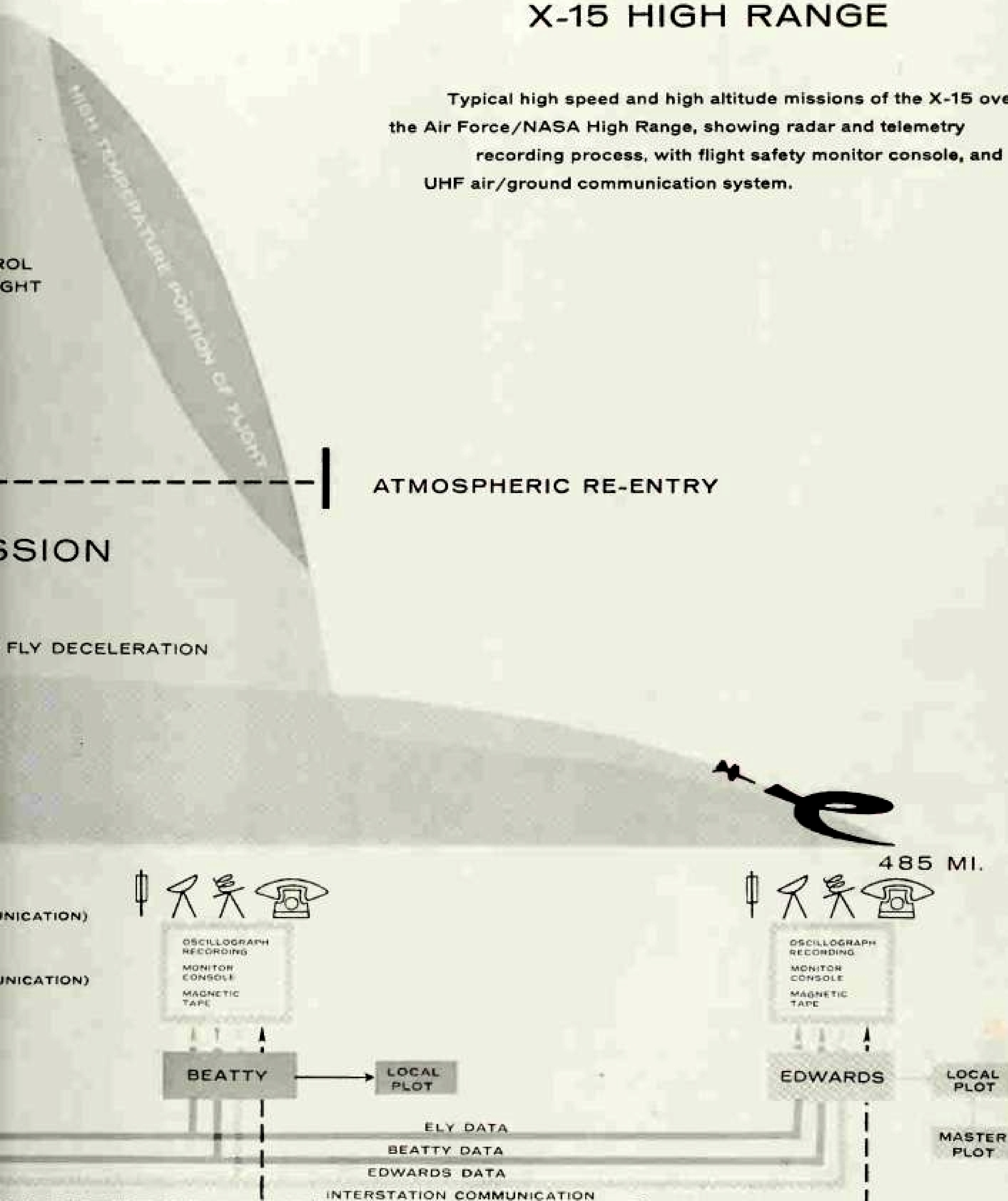




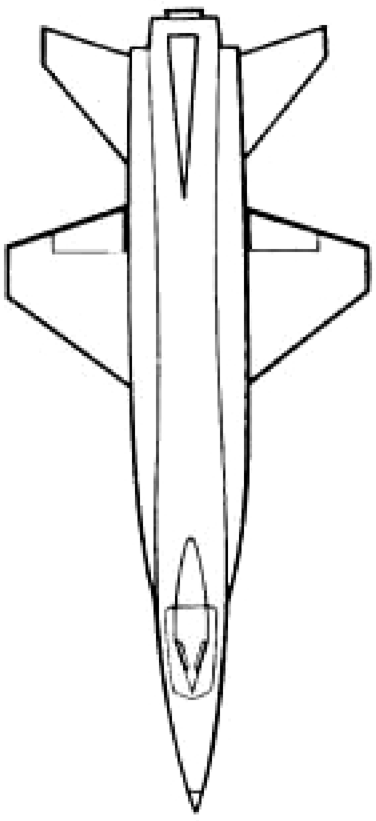
PATH OF X-15 varies if mission is aimed at high altitude or maximum speed. In either case, High Range instrumentation is ready to aid progress of flight and record the all-important data. High Range can ask 1,000 questions electronically of equipment on the ground and in the air from one to 10 times each second of flight time. These "questions" include 656 temperatures throughout the X-15, 104 different strain gauge readings and 140 pressures. High Range radar can pick up the position of a plane 400 miles away and plot its progress on magnetic tape.

X-15 HIGH RANGE

Typical high speed and high altitude missions of the X-15 over the Air Force/NASA High Range, showing radar and telemetry recording process, with flight safety monitor console, and UHF air/ground communication system.



North American Aviation

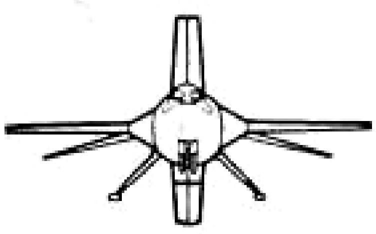


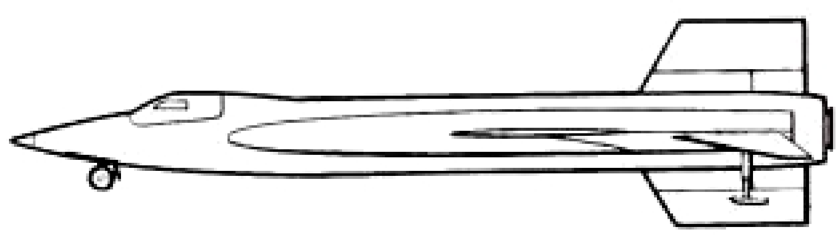
X-15

THREE VIEW

SPECIFICATIONS

LENGTH	50 FT
WING SPAN	22 FT
HEIGHT	13 FT
WING AREA	200 SQ FT
SWEEP $^{C}/_{4}$	25°
WEIGHT AT LAUNCHING	31,275 LBS



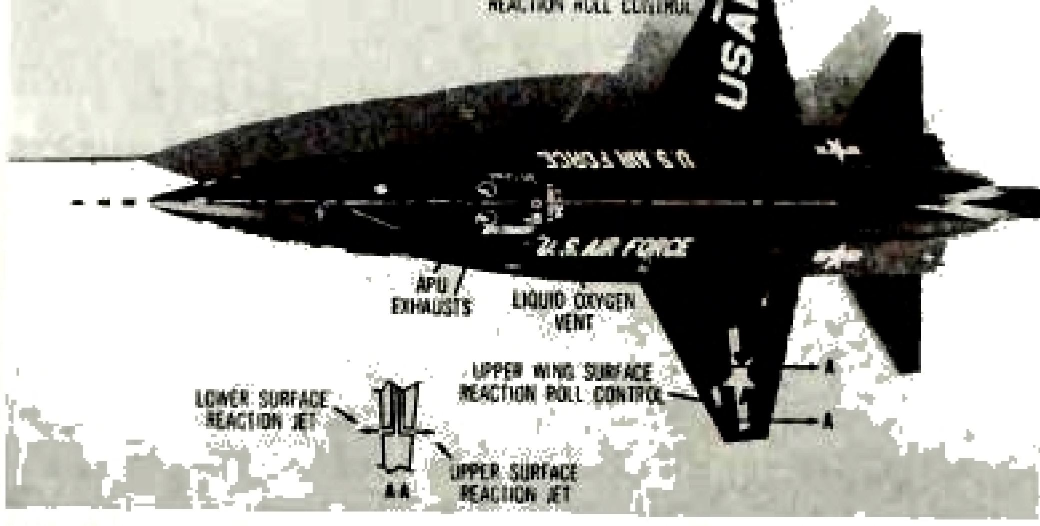


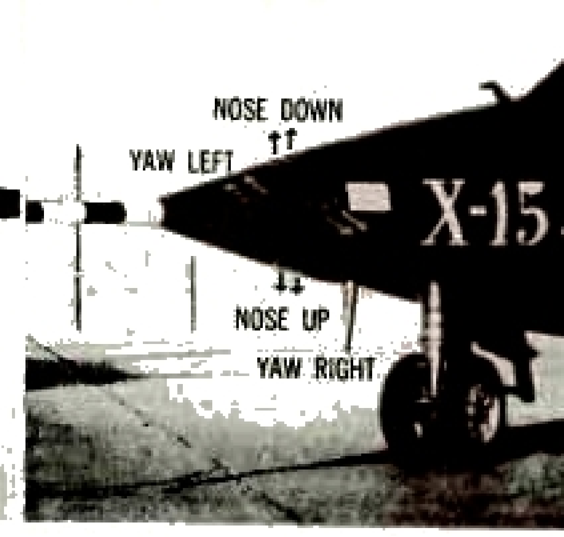
North American Aviation

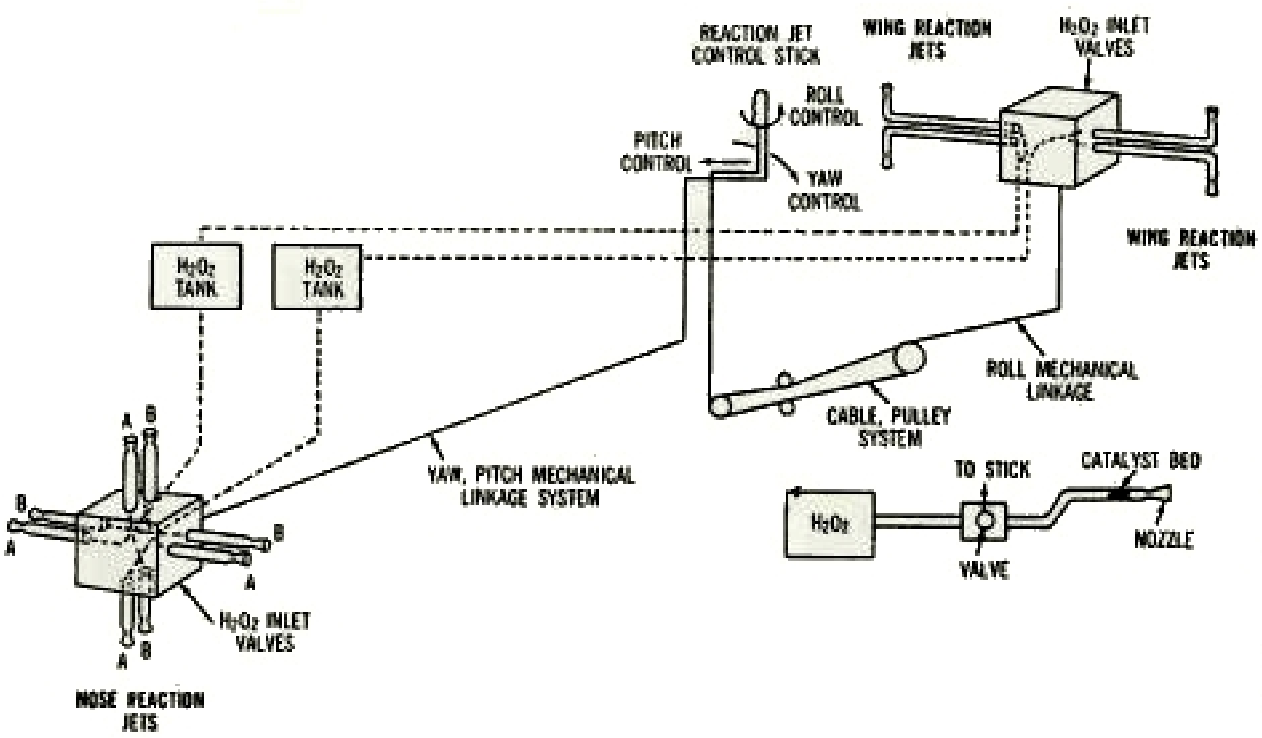
THREE VIEWS of X-15. Wing area of craft is 200 sq. ft. and weight at launching 31,275 lbs.

But no man just jumps into the cockpit of a new plane and takes to the air. Learning the controls of a new aircraft requires months and sometimes years of careful preparation. So it is with the X-15, for this plane encounters flight conditions never before experienced by human beings. This includes such things as weightlessness, re-entry—where much of the plane glows red-hot under temperatures of 1200 degrees Fahrenheit—and crushing forces of as much as 1,000 pounds all over the pilot's body.

Perhaps the most widely talked about of these is weightlessness. This occurs when the pull of gravity is balanced by the centrifugal force created by a plane as it speeds in a curving path away from the earth. The balance of these forces causes a state of zero gravity. A man standing in an airplane cabin when these two forces balance will actually float in





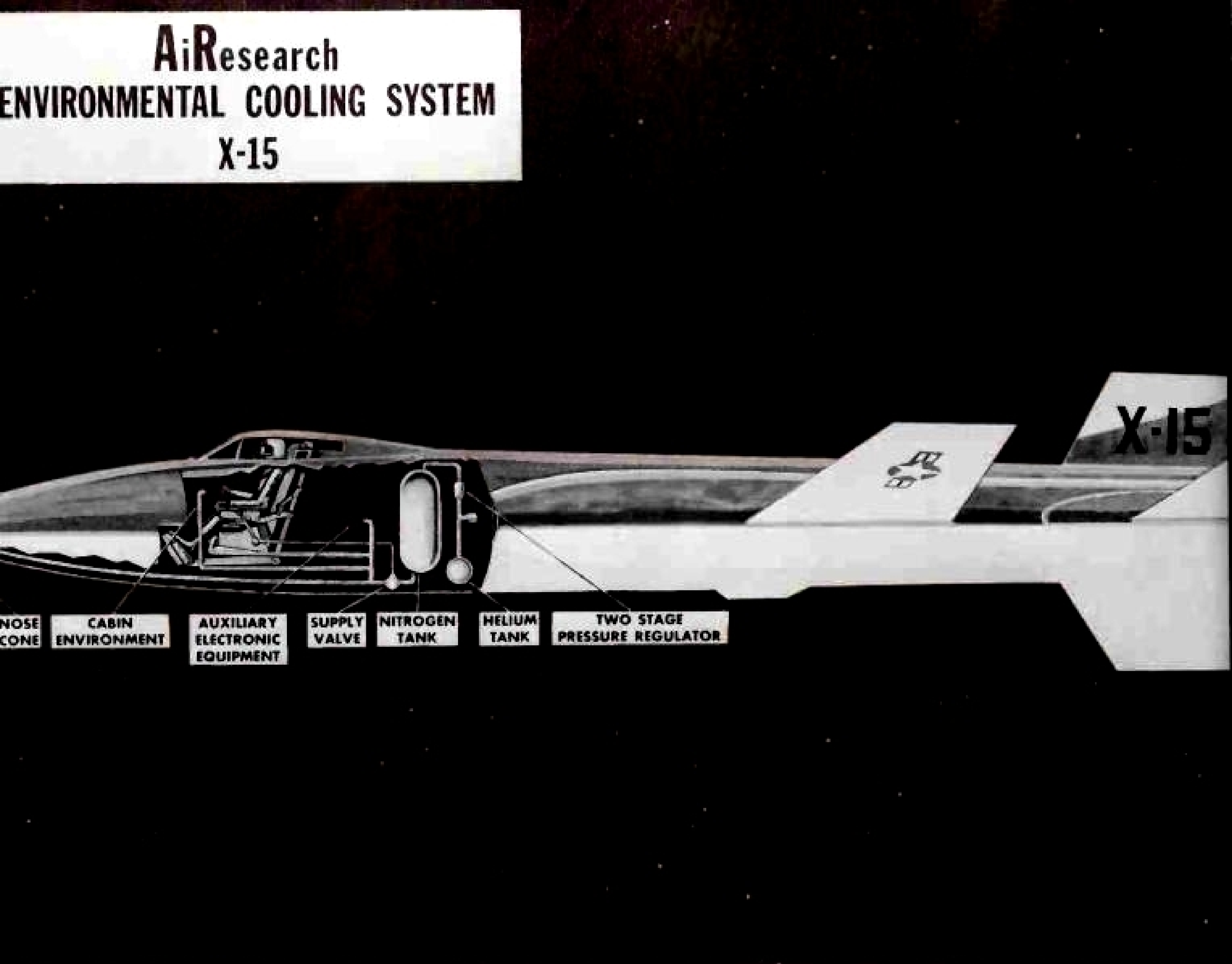


X-15 REACTION JETS are used for attitude control after burnout of the main engine. They are arranged in dual systems for fail-safety—in the nose, for example, the four "A" jets receive H_2O_2 from one tank and the four "B" jets from another, entirely separate one. Each system reportedly can provide about 113 lb for thrust pitch and yaw and 40 lb thrust for roll. The pressurized H_2O_2 used by the jets is activated across a catalyst bed designed by Bell Aircraft (left), expanded into steam, and ducted through a nozzle to produce thrust. The reaction control stick is completely separate from the aerodynamic control stick. It actuates proportional valves that control the flow across the catalyst bed.
Space Aeronautics

THESE SKETCHES show how hydrogen peroxide attitude controls work. The pilot's stick control is moved by wrist action only, since at the tremendous accelerations at which the control jets are used, he wouldn't be able to move his whole arm. By rotating the stick, he works the roll jets and by pushing it forward the pitch (i.e. up and down) motion of the plane. By moving the stick from side to side, the yaw jets are worked, moving the plane's nose to one side or the other. What happens when the stick is moved is that a mechanical linkage opens valves that permit hydrogen peroxide under pressure to flow over a catalyst bed. The bed expands the peroxide into steam. The steam then escapes through a nozzle, causing a force tending to move the plane in the opposite direction to which the steam is moving. Thus to yaw right, the pilot opens the two small jets on the left side of the fuselage nose. The system gives 113 lbs. of thrust for pitch and yaw and 40 lbs. of thrust for roll.

mid-air. Objects dropped from his pocket, such as a comb or a pencil, would not fall but would float beside the man. The effect on parts of the body also can be considerable. A Northrop scientist noted that prolonged stretches of weightlessness could cause acute nausea because food in a person's stomach might climb the stomach walls in the wrong direction. This would not be a problem in most cases, though, because the duration of weightlessness is relatively short.

The pilots of the X-15 must also prepare to withstand the effects of the tremendous pressures exerted on the body during extreme increase and decrease in speed. For this reason all the pilots had to ride the large whirling centrifuge at the Navy's Johnsville, Pennsylvania, research laboratories. Seated in a round

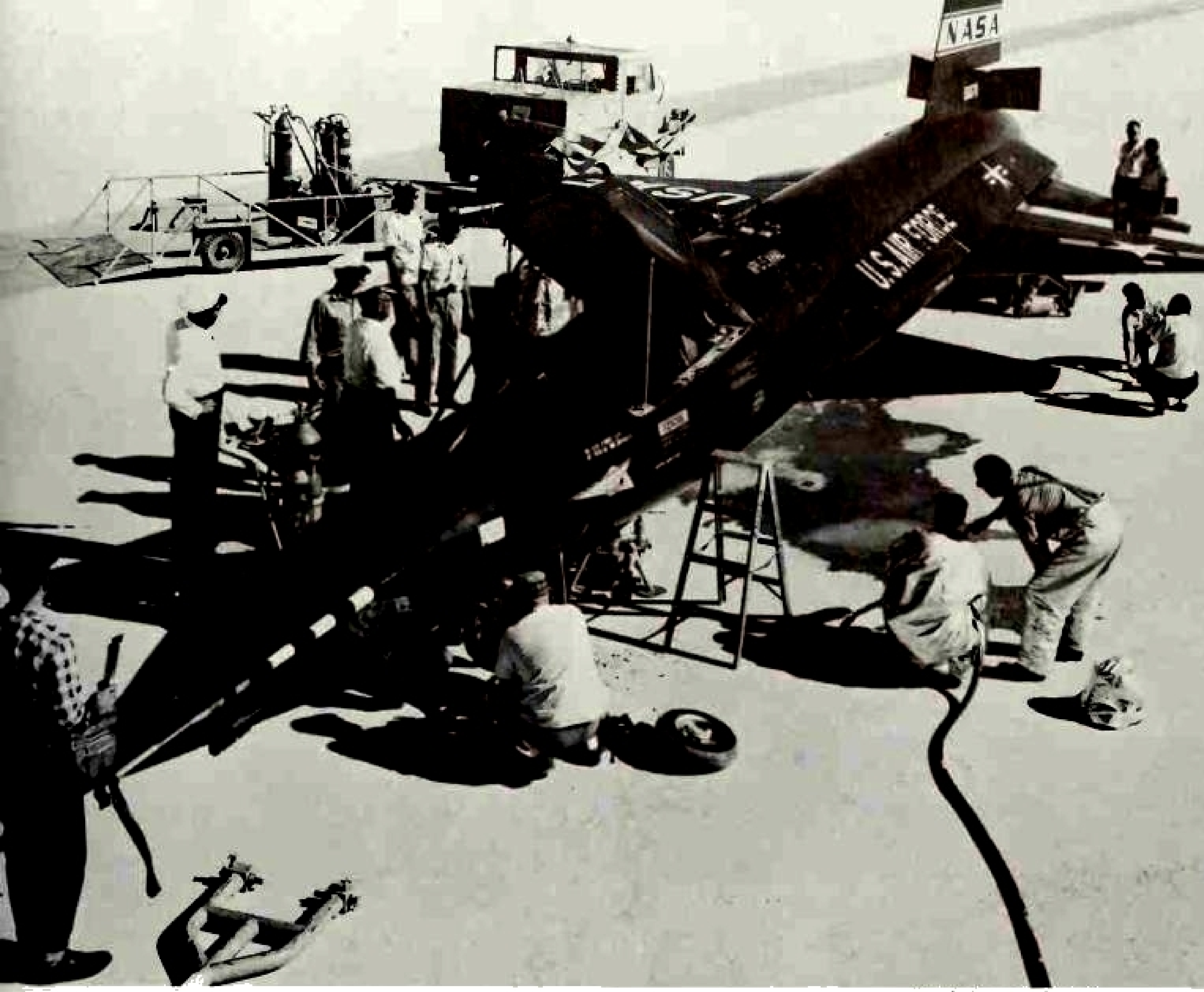


AiResearch Mfg. Co.

X-15 COOLING and pressurization system is shown in this diagram. The system, designed by AiResearch Mfg. Co. (div. of the Garrett Corp.), uses the pressure of helium gas to force low-temperature nitrogen through the system. The helium from the tank at left is lowered in pressure by a regulator, then allowed to slowly fill an expulsion bladder (not shown) inside the nitrogen tank. As the bladder expands, it forces nitrogen into the lines to do such things as cool the pilot's suit, the nose electronic package, etc.

capsule with simulated X-15 controls around them, each pilot was whirled faster and faster in a huge circle. This simulated the force of the rocket engines squeezing him back in his seat with a force of over 500 pounds per square inch. Sometimes the same equipment was used to simulate re-entry by rotating the capsule as it whirled around, causing a sudden pull-up that blanketed the man with 1,000 pounds of force per square inch. Through all this, the X-15 pilot has to show he can retain control of the craft.

Besides this, a special flight simulator was set up where the pilots could "fly" the plane on the ground. The simulator is a copy of the cockpit area with all the instruments that will be used in flight hooked up to a computer, a so-called electronic brain. Scientists set the computer to change the instrument dials to simulate actual flights and the pilot must



North American Aviation

ON THE DESERT at Mojave, flight crews check over the ready-to-fly spacecraft. Note the two-speed brake doors in the tail assembly, shown in the open position. This points up that the craft has two sets of controls — conventional wing-tail aerodynamic surfaces, used mainly during descent and landing, and the reaction jets used to position the plane in the thinness of the upper atmosphere.

turn the controls to meet the situation. For months and months before the first completed X-15 rolled from a hangar at Los Angeles International Airport, the X-15 pilots made hundreds of practice flights on the simulator, learning how the controls operated under all conditions. Even now, it's vitally important for a pilot to have several simulator runs just before he makes an actual X-15 flight.

While the X-15 was being built, Scott Crossfield, Joe Walker and the other pilots helped design a new, lightweight suit to help themselves withstand the pressure and the searing heat of re-entry. The multilayer suit is made of aluminized fabric and is complete with its own pressurization and air conditioning. The oxygen only enters the suit in a small sealed-off area around the pilot's face. The rest of his body is bathed in cooling nitrogen pumped from the environmen-

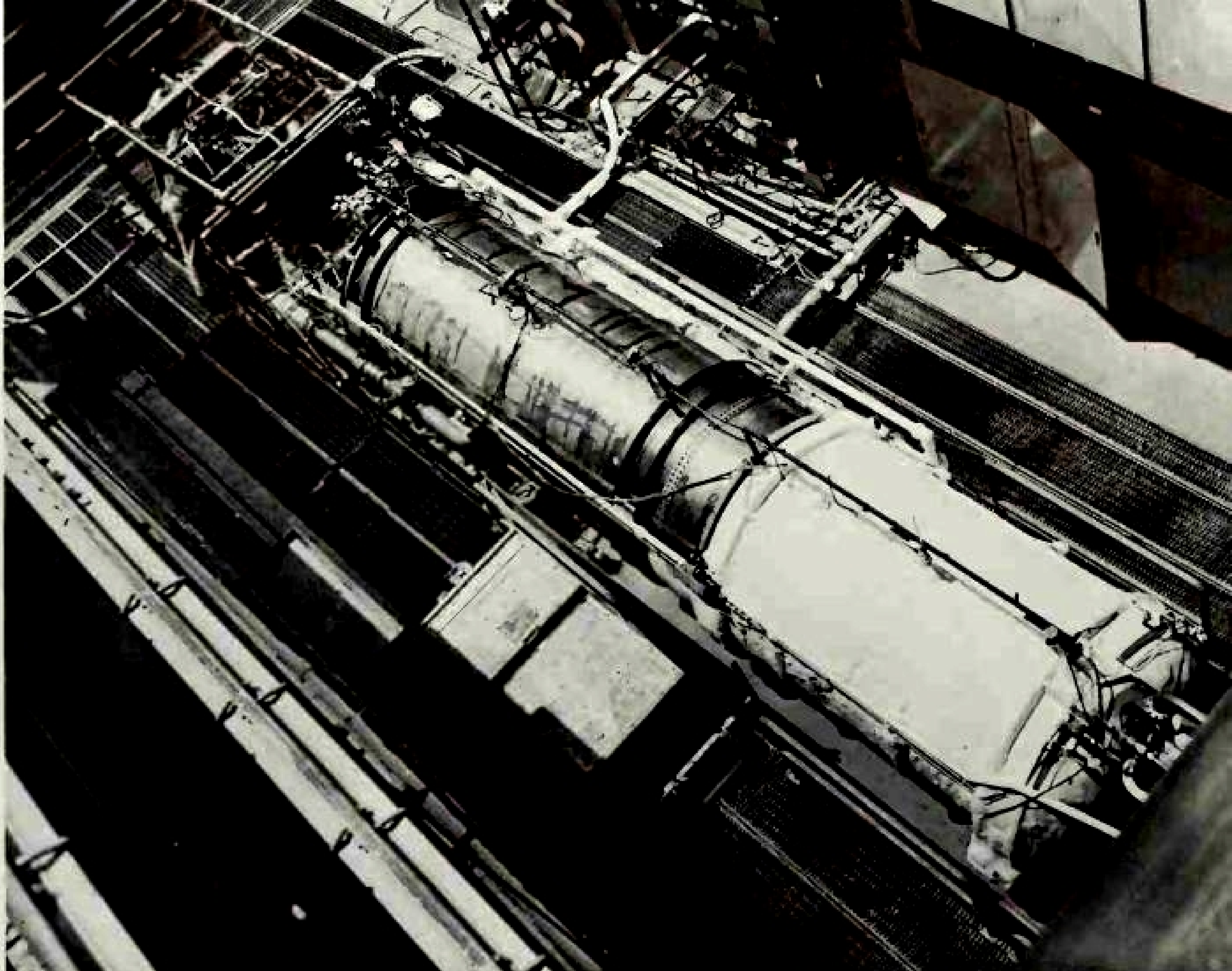
NASA

REAR VIEW of the X-15 shows the two skids used for the main landing gear. Black surface paint on craft is special high-temperature silicone-type coating which can withstand temperatures of over 1000 deg. F.

tal system developed by AiResearch Manufacturing Company, division of the Garrett Corporation. To test the different types of suits and to get accustomed to the heat extremes, the pilots spent many hours in special test chambers under the glare of dozens of heat lamps.

These are just a few of the wide range of tests the pilots had to undergo, each helping prepare him just a little bit more for the final test of skill and endurance that could mean success or failure of the first manned space craft.

As the plane was being welded and bolted together in the shops of North American and the pilots underwent their rigorous training, the last link in the chain was being established by engineers and scientists in the wild back country of the Mojave Desert and Southern Nevada. This was High Range. High Range

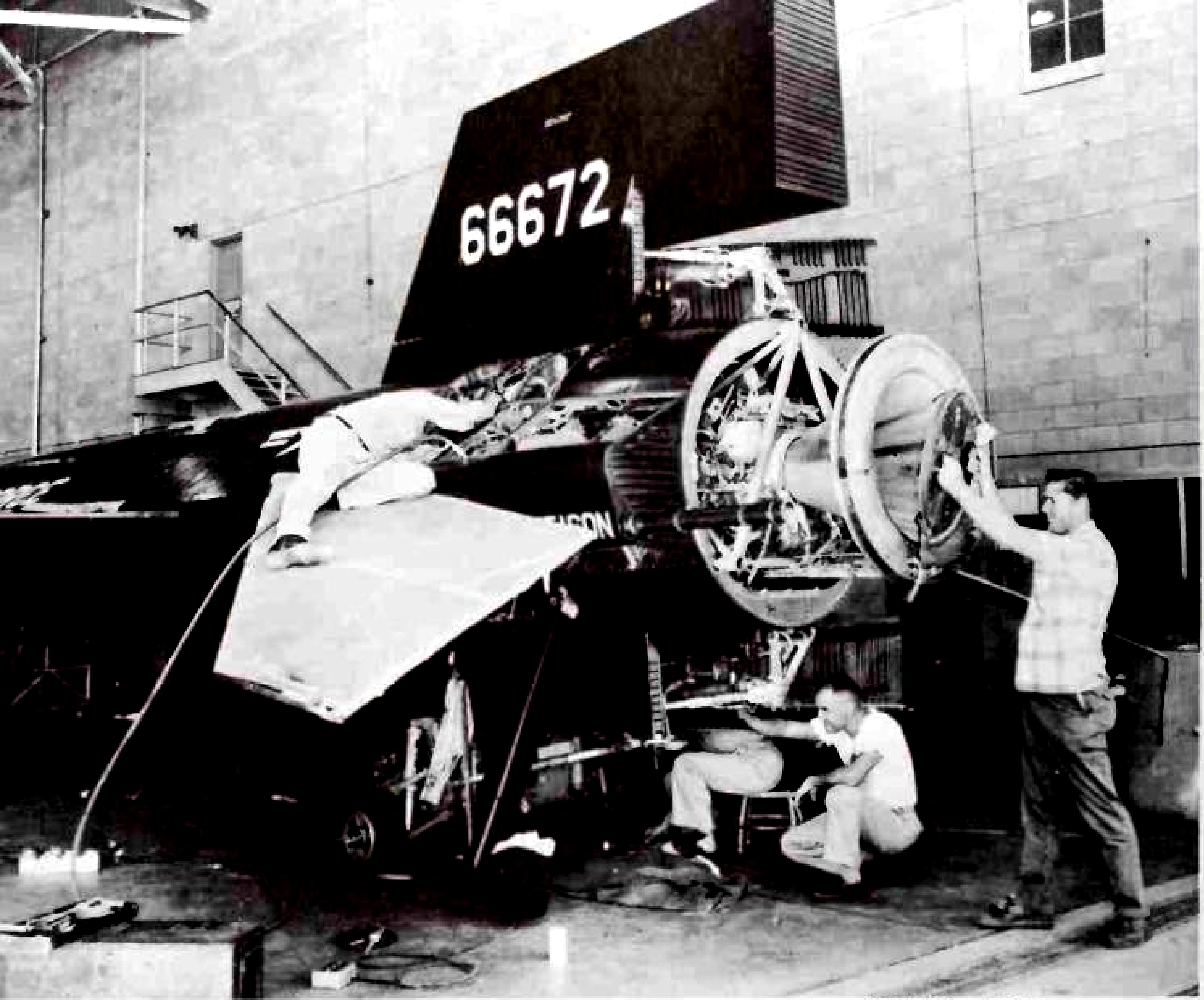


Thiokol Chemical Corp.

FIRST IMPORTANT strides in program were made with eight-chamber 16,000-lb.-thrust rocket engines. While many records were being set with these, more powerful engines were in development at Reaction Motors Div. of Thiokol Chemical Corp. Here the new 60,000-lb.-thrust powerplant is shown during development tests at Thiokol's Denville, N.J., test stand. The total length of the engine with fuel tanks is 30 ft., but the actual engine at left is less than seven ft. long and weighs less than a 300 hp automobile engine. The tanks illustrate the difference between the two types of propellant. The front one contains liquid oxygen, stored at temperatures well below freezing. Careful insulation of this tank is needed to keep the temperature low enough so the oxygen doesn't turn back into a gas, but still the outside of the tank is cold enough so it becomes covered with a layer of frost. The second tank contains anhydrous ammonia, which acts as the fuel for the engines and, as its clear outer surface shows, it can be stored at room temperature.

consists of powerful radio-electronic stations and associated equipment located at key positions along a path stretching from Wendover Air Force Base in northwestern Utah down to Edwards AFB, California. The function of this chain of stations spotted on mountains in wilderness areas is to provide communications and tracking data for the plane's flight. These stations mark the progress of each journey, compiling data for analysis by engineers and also radioing needed information on position to the X-15 and other aircraft involved in the tests.

By late 1958, the first of three X-15 test vehicles was rolled out into the sunlight in a corner of Los Angeles Airport and christened by Vice-President Nixon. Soon after, the sleek black plane was moved to Edwards AFB for preliminary tests. In early 1959 glide tests without power were made from the B-52 mother



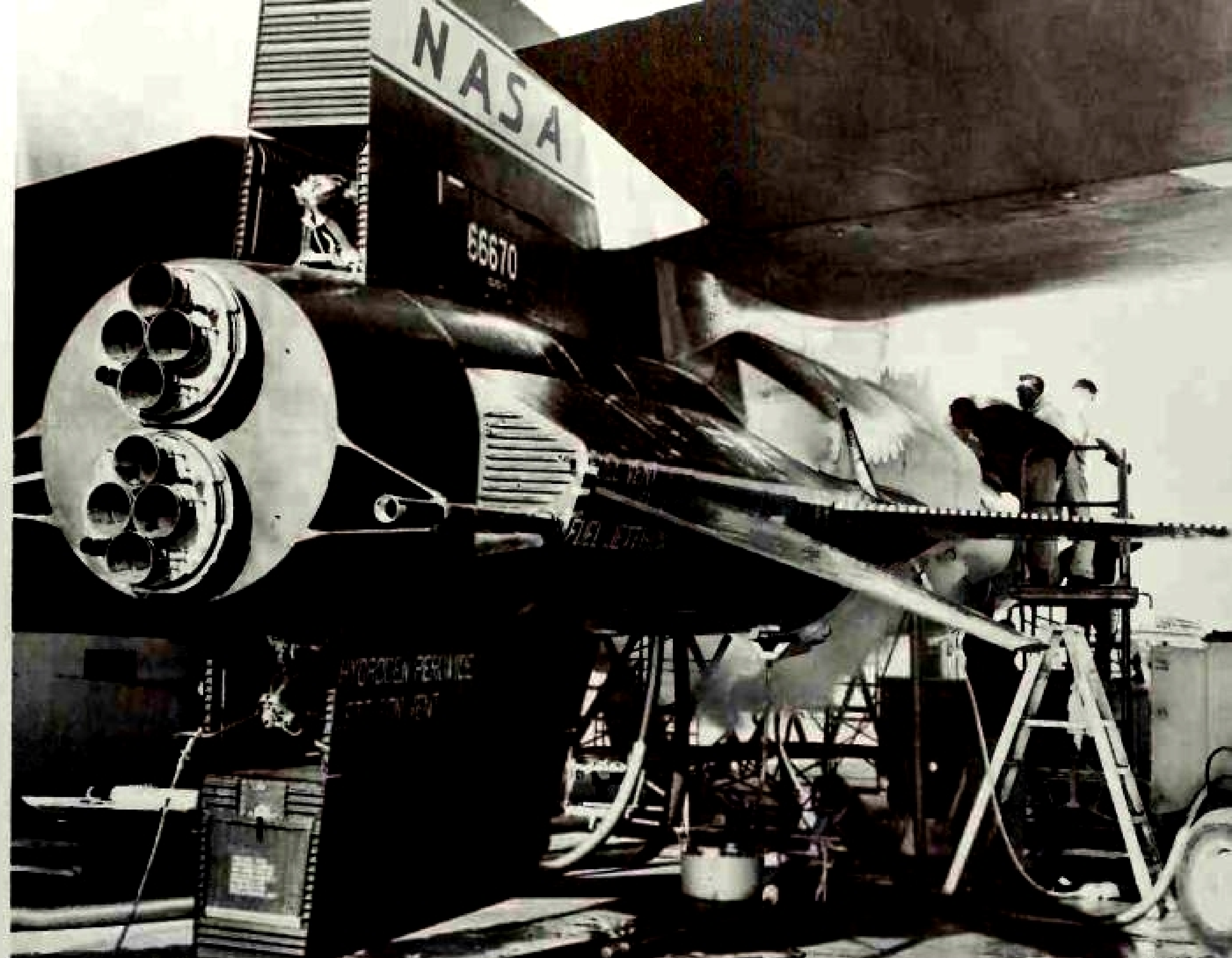
Thiokol Chemical Corp.

THE TESTED 60,000-lb.-thrust engine is shown being installed in the X-15 at Edwards AFB. Where the smaller engines used in previous tests had eight small exhaust nozzles, this engine has one large exhaust nozzle. With this engine, the X-15 finally realizes its capability ultimate of achieving altitudes over over 100 miles and Mach 5-6. On the first powered flight using this engine — Nov. 15, '60 — Scott Crossfield reached a speed of almost 1980 mph and an altitude of 80,000 ft.

ship to the floor of Rogers Dry Lake at Edwards AFB.

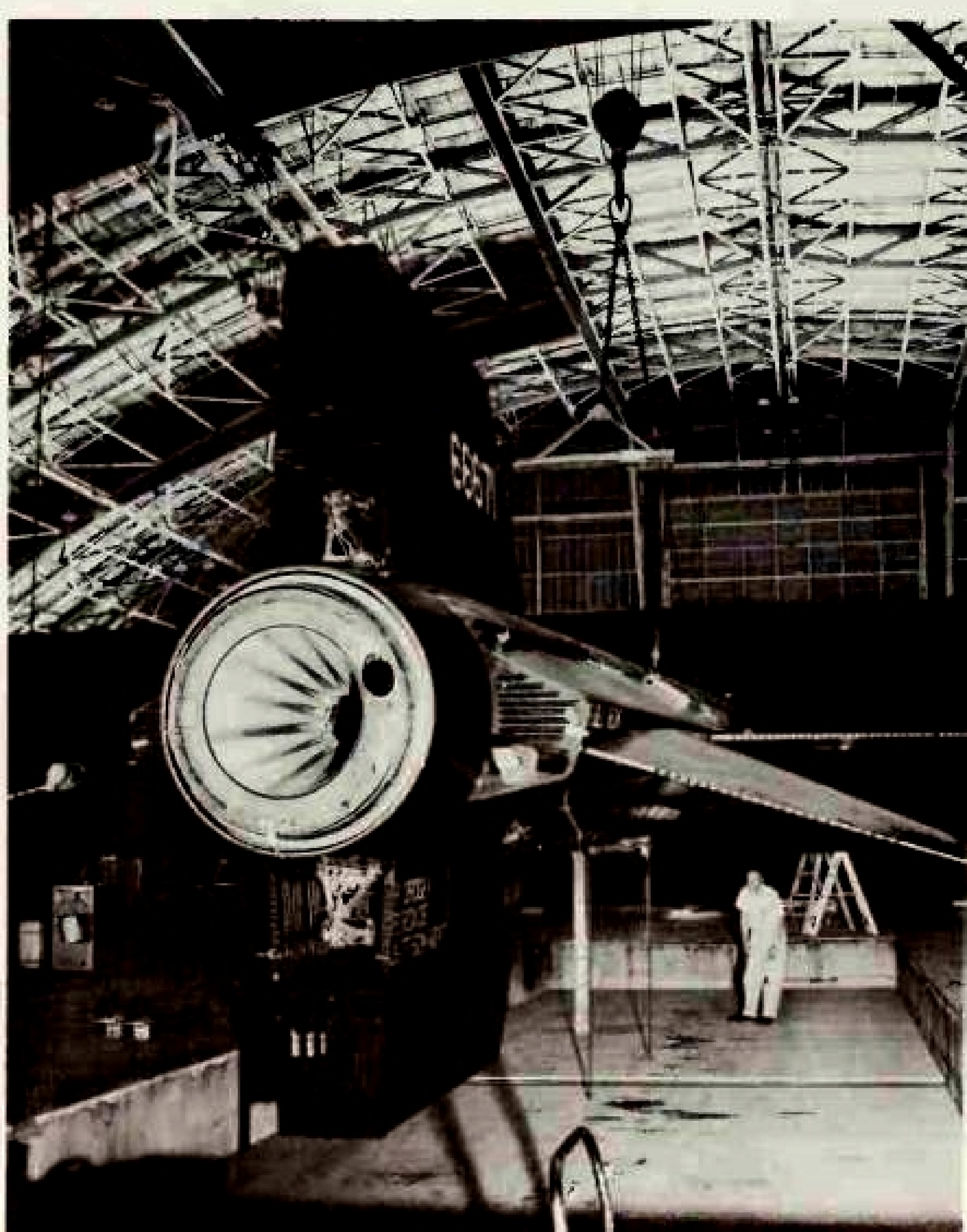
At this point there was a new test for the pilots.

We have seen what goes into the makeup of the various X-15 pilots — their experience and coolness in emergencies, engineering skills and the desire to pioneer. But when it comes to flying the jet-black space hot rod, something else is also needed. All of these individuals must act as a close-knit team. Scott Crossfield is the number one man, for his job as North American Aviation representative is to be the first pilot to fly each new plane or new modification. He proves the plane will work properly and do all it's supposed to before it is purchased by the customer — in this case, NASA. Thus Scott was at the controls on September 17, 1959, when the X-15's engines first roared forth after separation from the



U. S. Air Force

TWO REAR views show 16,000-lb.-thrust engine at top and more powerful 60,000-lb.-thrust engine at bottom. To run the engine, the LOX and fuel are valved into the combustion chamber and ignited, the liquid oxygen providing the oxygen needed to sustain burning. The exhaust gases resulting from combustion are ducted out the end of the plane through the nozzle(s) with tremendous force. In accordance with Newton's Law, the reaction to this force moves in the opposite direction, forcing the plane forward. The principle is the same as the motion obtained with a toy balloon if it's filled with air and the air is then suddenly released through the neck of the balloon with the balloon free to move.



North American Aviation

U. S. Air Force

AS FLIGHT time nears, engineers move in with delicate electronic equipment to perform key checks on systems.

B-52 at 35,000 feet in the first powered flight. On this day, Crossfield reached an altitude of 52,000 feet and an impressive speed of 1,385 mph — Mach 2.1. It is not his job, however, to probe the edges of space or throw the throttle wide open. This role falls to Joe Walker, Bob White and the other NASA and service pilots.

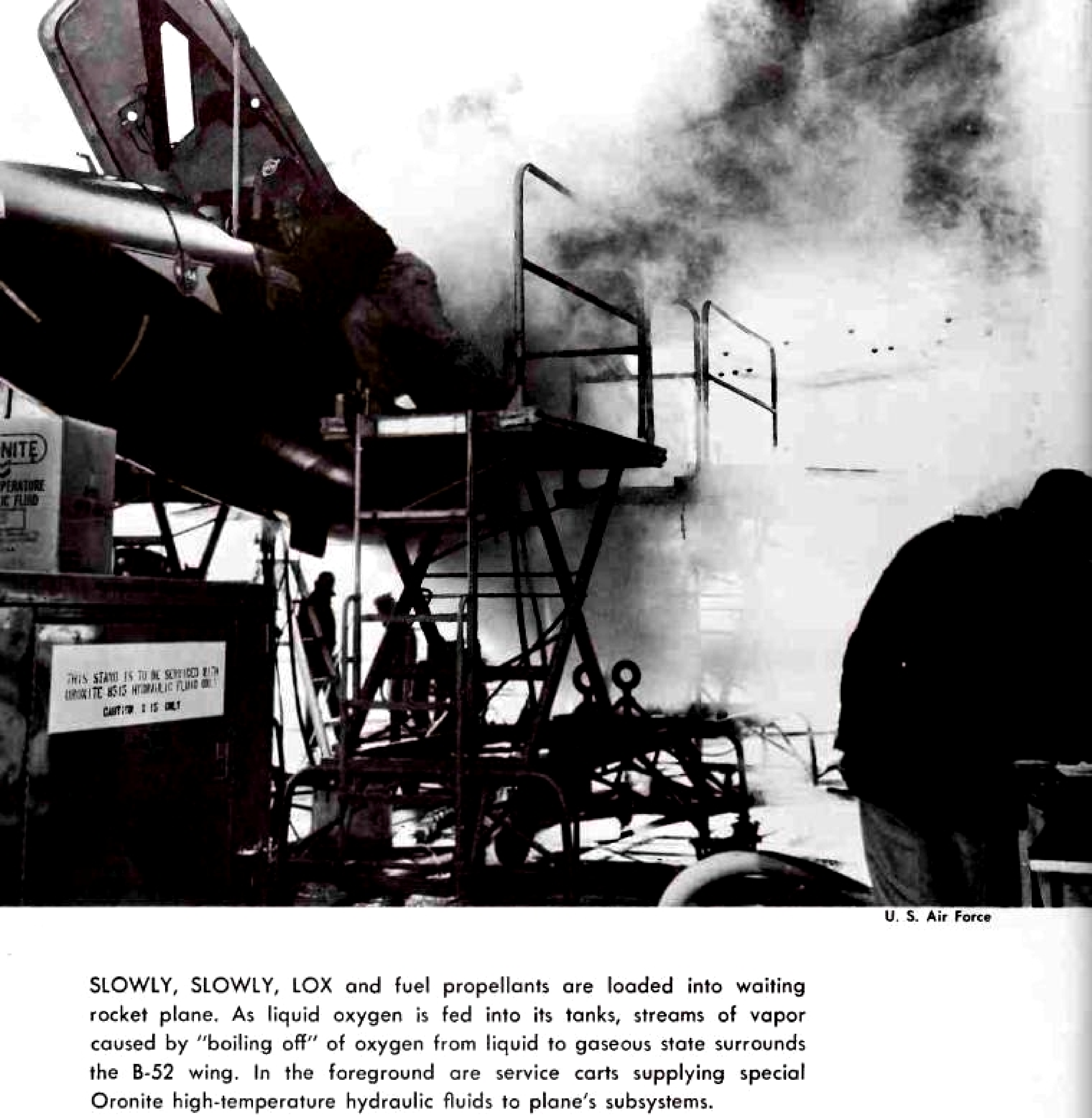
In a typical X-15 flight, all the pilots have a job to do. If Joe Walker is to fly the plane, Bob White will go along in the B-52 cabin to give advice, watch out for danger signals on the instruments located in the mother ship and also see how the X-15 behaves from the outside. The other pilots may fly chase planes. For Major White's record-breaking altitude run, Commander Petersen, Captain Rushworth and John McKay flew chase in an F-100A and F-104s. A chase pilot's job is to cruise behind the X-15 and observe its movements, first when it's dropped

U. S. Air Force

ON FLIGHT DAY, dawn breaking over horizon at Edwards AFB finds technicians winding up six-hour-long job of installing plane and checking it out on B-52 mother ship.

from the B-52 and later when it comes in to land. Perhaps the chase pilots can see some possible trouble in the making and warn the X-15 pilot to take corrective action. Thus when the plane's engines exploded during the third powered flight in September 1959, it was Major White flying chase who radioed the warning of "fire" to Scott Crossfield. It was this warning that told Crossfield to shut off the engines in time to avert disaster.

On the day of a typical X-15 flight, normal sleep is a forgotten thing for the engineers and ground crew. Work on the plane starts at midnight. All through the early-morning hours, check after check is run as the X-15 is cradled into position under one wing of the B-52. Auxiliary power units are run up, control surfaces are carefully examined to make sure they're pin-point accurate, electronic devices are attached to circuits through-



U. S. Air Force

SLOWLY, SLOWLY, LOX and fuel propellants are loaded into waiting rocket plane. As liquid oxygen is fed into its tanks, streams of vapor caused by "boiling off" of oxygen from liquid to gaseous state surrounds the B-52 wing. In the foreground are service carts supplying special Oronite high-temperature hydraulic fluids to plane's subsystems.

out the plane and dials and small warning lights minutely studied by watchful technicians. Finally, as the first rays of dawn appear, the engine propellants — liquid oxygen and water-alcohol or anhydrous ammonia fuel — are carefully pumped into the plane's tanks.

Slowly the fuel gauges rise toward the full mark. Extreme caution is needed during this operation because the propellants are toxic and volatile. One slight mistake and the craft could be ripped apart like a child's toy. Finally, as the field becomes bathed in the gray light of early morning, the service carts are pulled away and the electronic checkout gear disengaged. The pilot for the day checks over the plane from the outside, then settles into the cockpit for a further check of his instrument panel. The B-52 crew climbs aboard and similarly checks out the huge bomber and the links to the

U. S. Air Force

AS MORNING wears on, service carts are wheeled away from B-52 and crew members make last check of ship's vitals before giving the final O.K. In other parts of the field, X-15 pilots not flying the ship today are getting ready to fly chase in F-100s and F-104s.

X-15 fastened to its wing. At nine A.M., all is found in good order and the B-52 taxis out on the Edwards runway and takes off for the launch area above 40,000 feet.

All the way up the checks continue between B-52 and X-15, both planes and the ground stations, and B-52 and X-15 and ground stations with the chase pilots. Once at B-52 cruise altitude, the vital final six- to seven-minute countdown before powered flight begins. Carefully the X-15 pilot, listening simultaneously to advice from engineers and fellow pilots on his radio, begins to turn on the switches.

"No. 1 APU [auxiliary power unit] started fine," the X-15 pilot says. "No. 2's starting slow."

From one engineer to another: "Blake, how about it?"

"I'm watching the gauge — it's a little slow, but it's up to speed now."

From the X-15: "APU okay now.

U. S. Air Force

FINALLY, after long hours of checking and rechecking by engineers and technicians and pilot briefings, the man of the day, the X-15's human occupant, straps himself in his narrow seat. Here, waiting for the cockpit canopy to be snubbed down over his head, is Joe Walker of NASA. The X-15 pilot enters the plane on the ground and remains in the cockpit, checking his instruments and gear all the while, as the B-52 takes off and climbs to altitudes of from 35-45,000 ft.

How does it look from the ground? Are we all right to fire?"

Engineers on the ground study their gauges carefully and check between themselves whether the values indicate all is in working order on the plane.

"Harry, how about it?"

"Looks good here, how's the other gauge?"

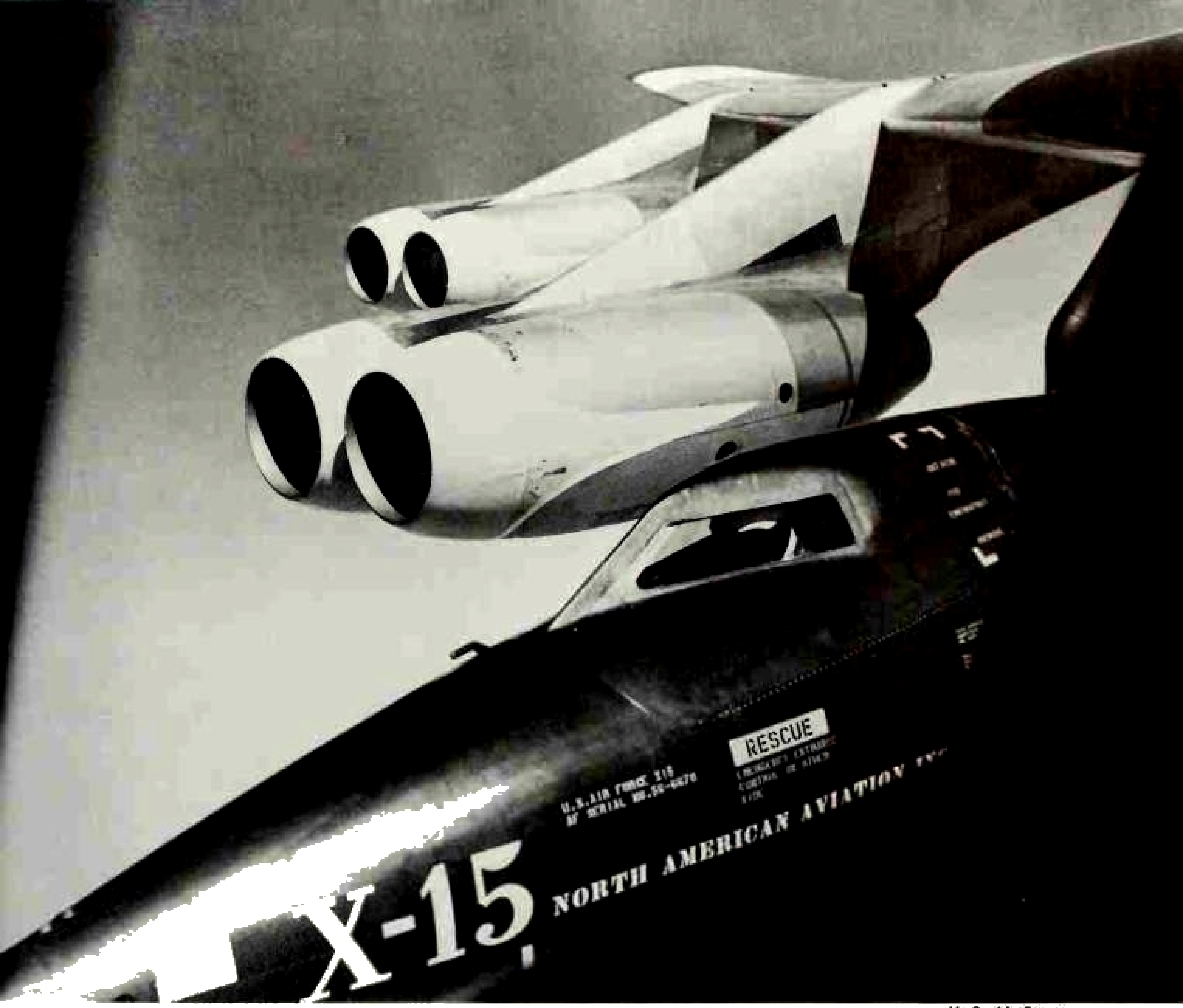
"All right by me, let's go!"

"Ok, X-15, give it a try."

The B-52 crew readies itself for the X-15 drop. The X-15's engines aren't ignited until the plane is free of the bomber.

How does it feel those last few minutes before launch?

Says Joe Walker, "It's a feeling I imagine a bronc rider must have when the helpers open the gates. You're braced, ready to go, your muscles all primed for the important step of starting the engines after the plane drops. Then suddenly

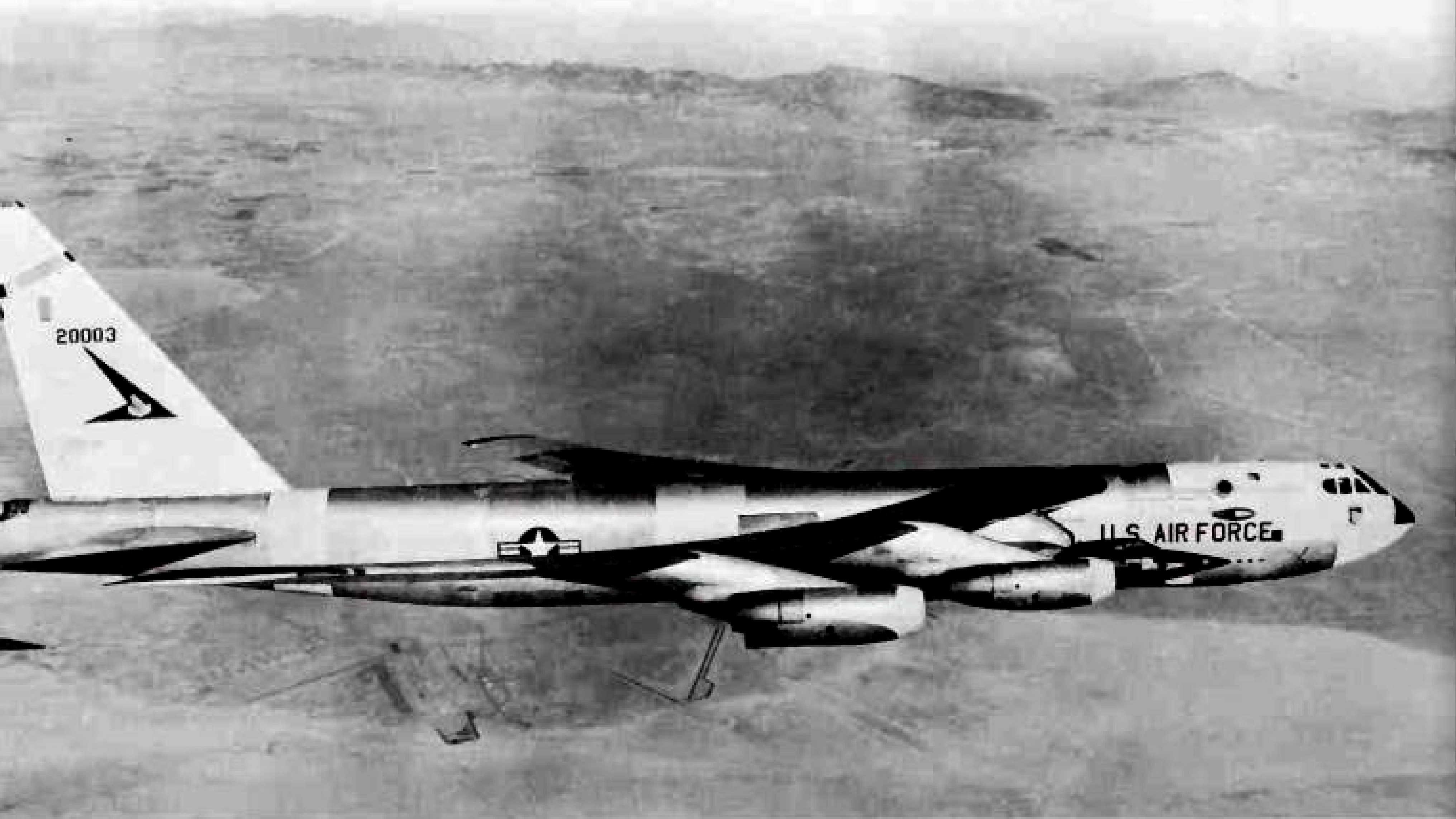


U. S. Air Force

BOMBER'S-EYE VIEW of X-15 shows the plane as the final point-of-no-return nears when, at the go-ahead signal, the B-52 crew releases the slim, black contained-package-of-dynamite from its B-52 nesting place. At this stage of flight, hundreds of gauges and oscillographs are being studied on the ground, in the B-52, in the X-15 itself to see if all systems are working properly. One by one the X-15 pilot flicks the "on" switches for all the systems except the engine ignition, for the engines aren't started until just after the plane drops free of the bomber.

you're free. You turn 'em on and with a muffled roar and a slight boot — certainly not as great a kickback as you might get from a rifle — you're on your way."

If this is a high-altitude mission, the pilot soon points the plane's nose toward the heavens and it rises steeply, the bright flames from the engine exhaust flaring down through the thin air of the upper atmosphere. The first few minutes of this flight are critical, for total engine burning time is only three to four minutes. In this period of time the pilot must line the plane up properly to glide to the desired altitude in the correct position for return to earth. By the time main engine burnout occurs, the plane is committed to a ballistic trajectory in which it is just like an artillery shell lobbed into the air from a huge cannon. The only thing the pilot can do at this point is to control the attitude of the plane by means of the small



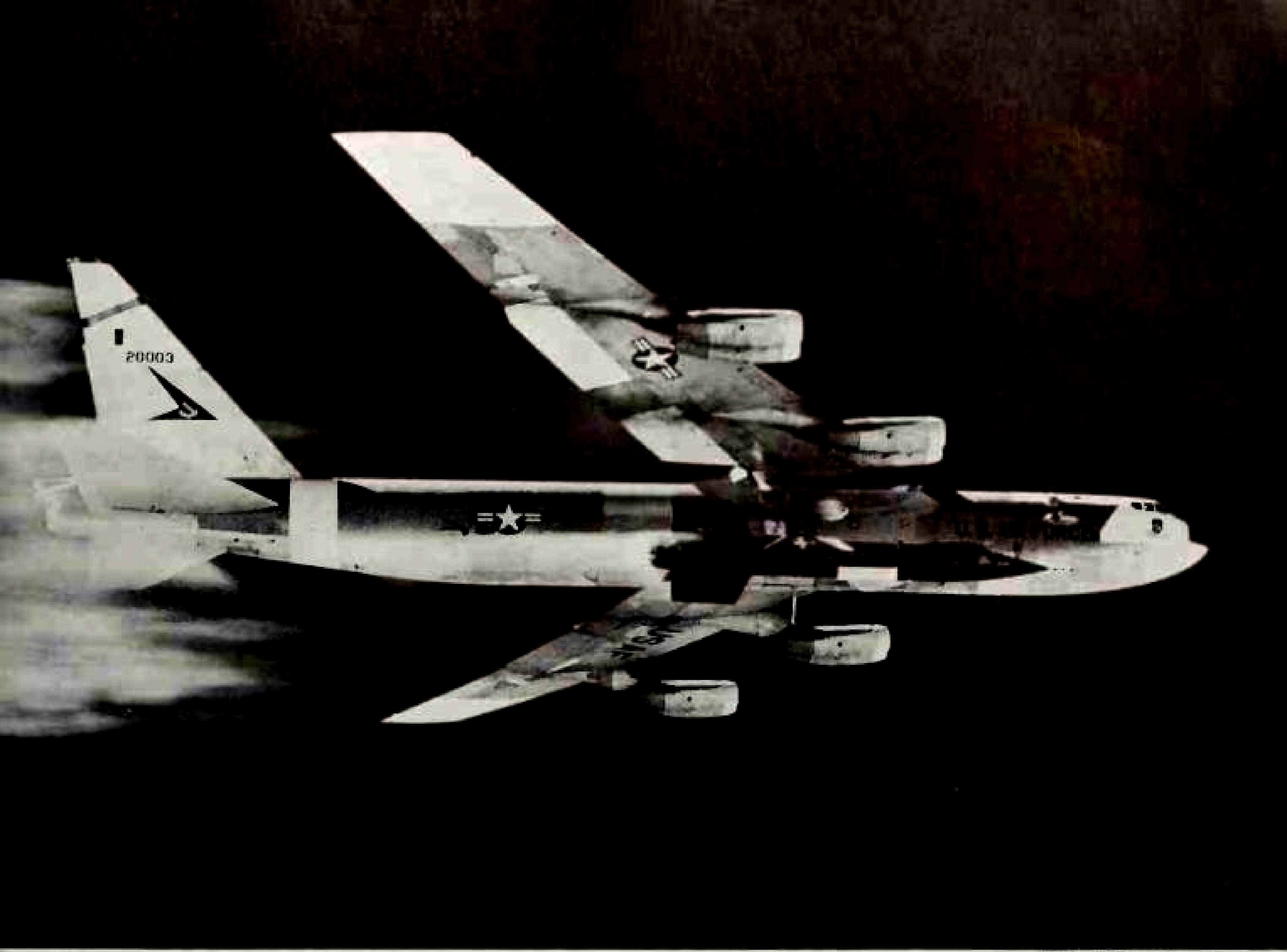
U. S. Air Force

CHASE PILOT'S view of the soon-to-be-launched X-15 is also important. Each chase pilot carefully watches every movement of the plane. The slightest hint that something isn't working as it should may cause the chase pilot to tell the B-52 crew to cancel the flight.

hydrogen-peroxide jets located in the nose and wing tips, for the normal aircraft control surfaces are useless until it reaches heavier atmosphere again.

The plane moves upward toward the edge of space 100 miles above the earth's surface in a great glide, slowly losing momentum until it reaches the apex of flight at extreme altitude.

"When you're 'on top' at such heights," says Major White, "if you glance out it's a different universe you see. Above you the sky is black and where there is lighting below and toward the earth it's a very pronounced deep blue. There seems to be a very distinct dividing line showing a lighter blue near the earth's surface. And you can see such a greater area — it seems as though you can see much greater distances than you've ever seen before. At the top of the trajectory you have some periods of weightlessness. It's



U. S. Air Force

THREE, TWO, ONE — go — the X-15 jockey braces himself for this moment as the craft separates cleanly from the high-flying bomber. The engine is switched on and the blast of the exhaust tells all concerned that another successful research flight is under way.

a funny feeling, but you've experienced so much of it, it occurs for such a brief time — less than a minute — and you have so many things to do you hardly notice it."

From near the top of the atmosphere the plane is headed back down, gathering speed much as a roller-coaster car does after going over the top of an incline. Closer and closer the plane comes to re-entry altitude and the pilot must use every ounce of skill to keep the plane in the right attitude for re-entry. Re-entry is that portion of the flight in which the ship returns from the thinness of near space to the relatively dense atmosphere below. The friction between the onrushing craft and the air causes the surfaces of the ship to get hotter and hotter until parts of it reach the fantastic temperatures of 1200 degrees Fahrenheit. To return safely, this heating must be taken by

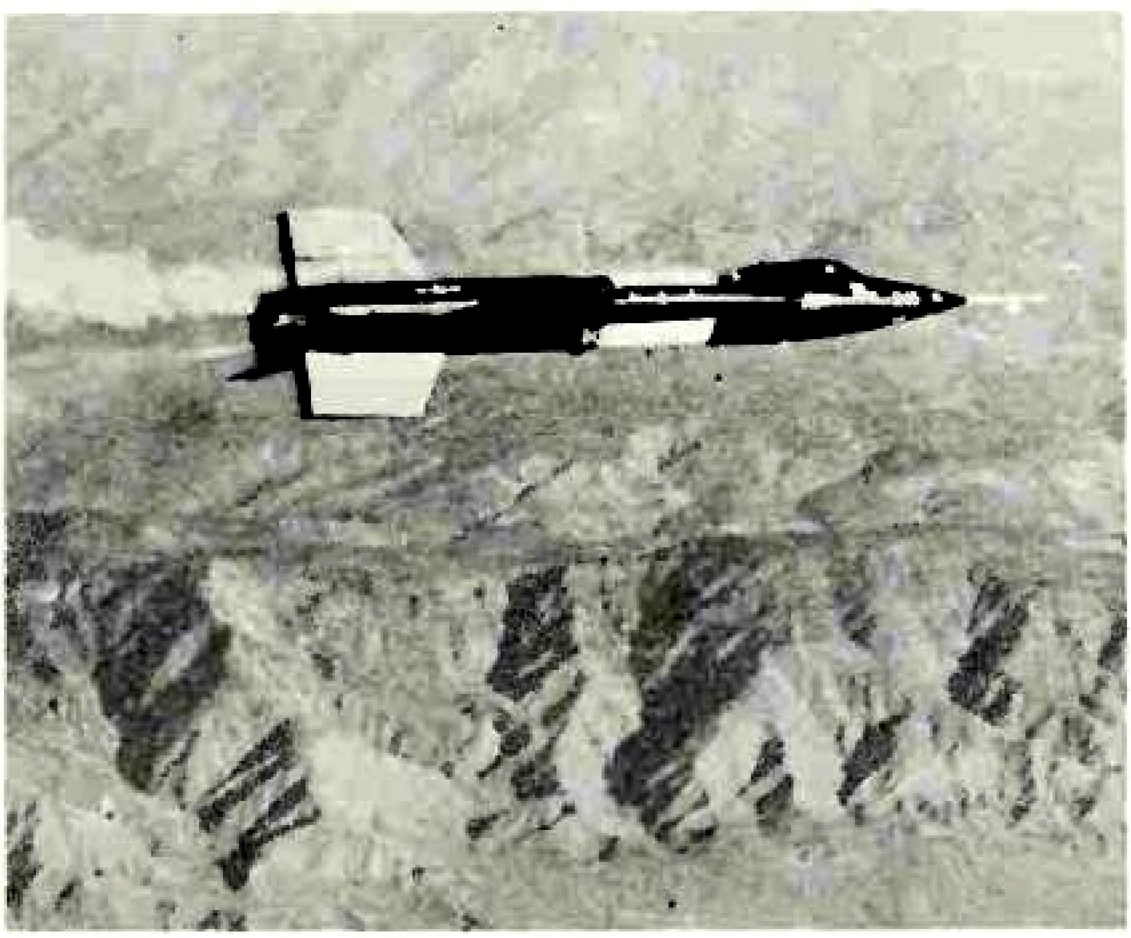
U. S. Air Force

SPLIT SECONDS later the X-15 is fully clear of the mother ship. Let's hear how Major White describes his flight sequence the day he first set a new world's altitude record. "I lighted all thrust chambers while monitoring an eight-degree angle of attack. The plane was separated at 45,000 ft. and dropped to 39,000 ft. until application of thrust arrested the initial altitude loss and the climb was maintained to 60,000 ft. At this altitude, I speeded up to Mach 1.9, then started a 1.5g pull-up and maintained this g-level until attaining a full-back stick at 18.5 deg. angle of attack." The engine continued firing until all the fuel was exhausted at 118,000 ft., after which the plane glided the rest of the way to "on top" in the edges of space.

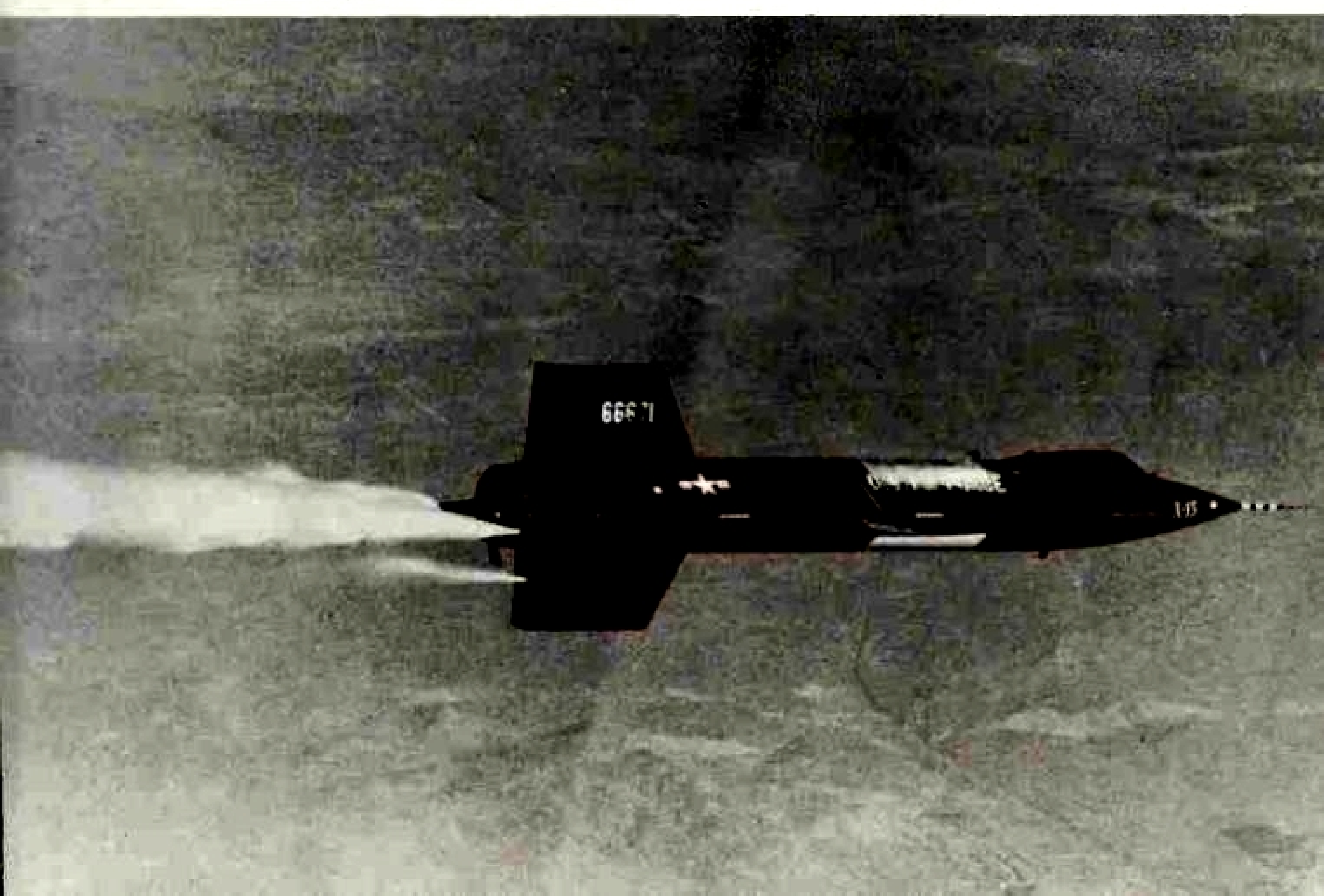
the leading surfaces of the plane, such as the wing leading edges and nose, and dissipated before it can get to the pilot's area. Just as you can pass your finger swiftly through a flame without hurting it, if the plane is held to the correct position it will be undamaged. But if the ship comes in at the wrong attitude so it hits like a stone, then it can reach extreme temperatures all over its structure at the same time. If this happens, the craft and its pilot can burn up like a meteor.

As the plane hits this heat barrier, the pressures and the extremes of environment might possibly confuse the pilot as far as knowing the correct attitude the plane should be in. To aid him, a Q-ball sensor, a delicate electronic device developed by Northrop Corporation, has been installed in the plane's nose. Glowing red

AS THE PLANE moves away from the B-52, these views show how it appears from the chase planes with engines and accessory systems all operating smoothly — the end result of thousands of man-hours of engineering, pilot training and ground crew work. Faster and faster the craft goes until the pilot pulls the nose up and "heads for the heavens."



U. S. Air Force



NASA

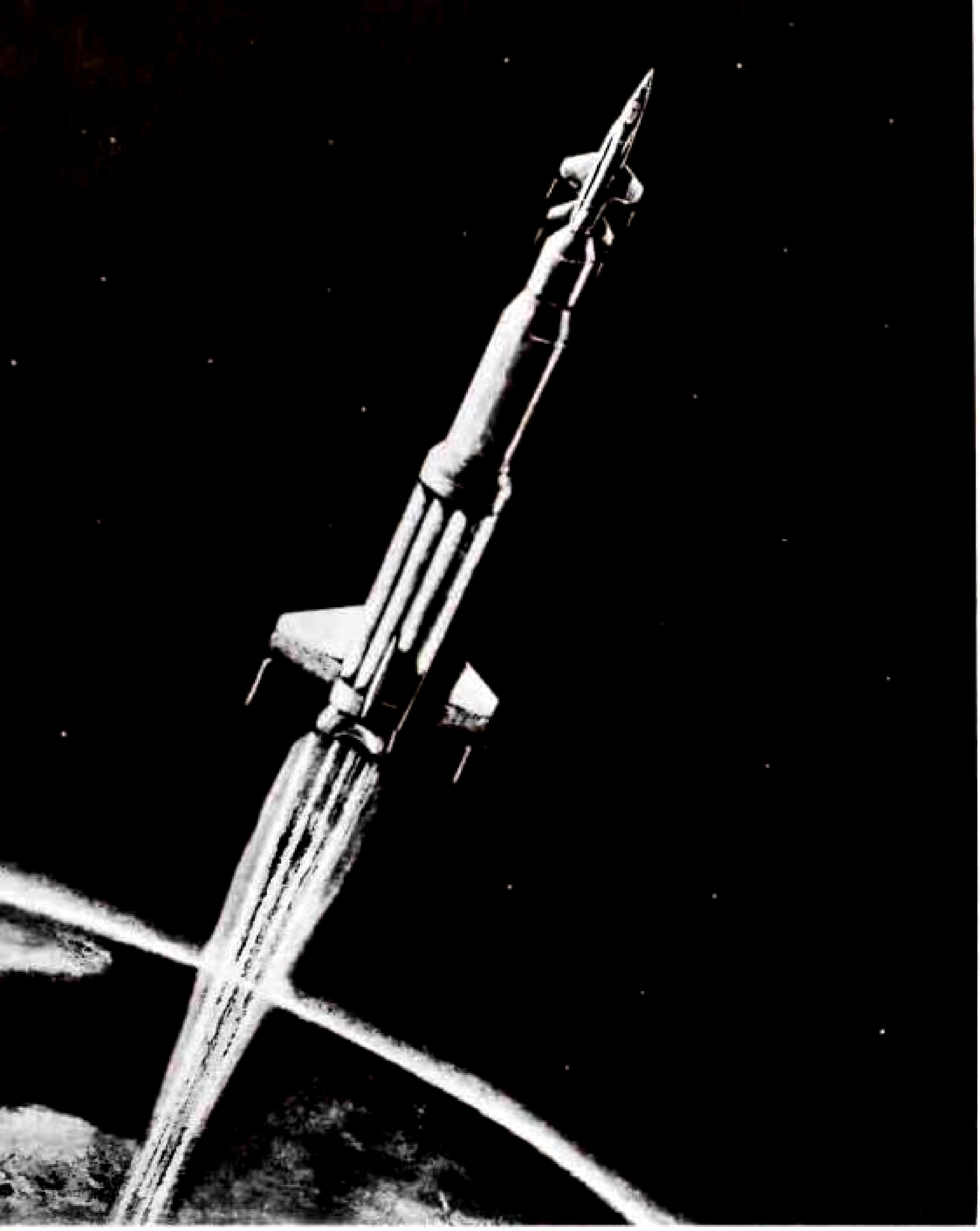
OVER THE TOP and down the plane goes, re-entering the atmosphere with leading edge surfaces flaming hot under temperatures of over 1000 deg. This is hot enough to turn everyday metals, such as aluminum, low-grade steels and other familiar, seemingly indestructible materials, into liquid pools or putty-like forms. But such temperatures can do little more than momentarily heat up the nickel-base X-15 structure if the ship re-enters at the proper angle. After this brush with death, the craft glides smoothly back toward earth to finally mark the end of another successful step toward space travel with this mile-long run over the white, hard-baked surface of Rogers Dry Lake.

as an ember, this senses the plane's position and transmits data telling the correct position the ship must take to avoid burning up.

Down into the atmosphere the X-15 plunges until, at about 30,000 feet and no longer in a ballistic trajectory, it can be guided with wing and tail surfaces for the long glide toward the landing field. All of this requires tremendous skill and split-second timing, for with no main engine power available, the pilot has only one shot at the landing strip. By the time the ship is near Edwards AFB, it's come down to about 15,000 feet and is traveling about 277 miles per hour. To land, the pilot must execute a huge spiral downwind turn, circling the field first at 8,700 feet, then at about 5,800 feet. At 3,200 feet, the pilot uses air-braking surfaces for landing, cutting his speed slightly, but still touching down at 207 mph for the

MISSION ACCOMPLISHED, Air Force Major Bob White smiles happily as ground crew members unfasten his gear. Out of the plane, he discusses the events of the flight with other officers, later will sit down to go over highlights with engineers and researchers.

U. S. Air Force



Thiokol Chemical Corp.

BEYOND the present test program, researchers are already looking at possible future uses for the X-15 design. One such possibility, shown in this artist's sketch, would be to mate the ship with a large rocket booster for orbital and space exploration missions.

close-to-a-mile landing run along the desert floor.

As the plane comes in, the pilot must first jettison the lower part of the tail. This section, aerodynamicists discovered, was needed to provide proper control of the ship, but it sticks out farther than the landing gear and thus must be dropped before the plane comes to earth. As the lower tail hurtles to earth, the pilot starts the release mechanism for the two long skids at the aft end of the plane that form the main landing gear and the twin-wheel nose gear. Carefully he lines up the plane with the landing strip, straightens the wings, makes sure that the plane is at just the proper angle with the earth for initial touchdown of the skids. A slight miscalculation, one wing tip too low or the skids at the wrong angle, could be disastrous. With no power, there's no second go-round. But the many hours of

HIGH RANGE monitoring station in Nevada

practice plus experience and pilot's feel of the craft stand him in good stead as the skids contact the ground. The X-15 glides along on the skids alone for several hundred feet. Then the plane is nosed down slightly until the nose wheels touch the ground and another successful flight is in the books. The plane comes to a halt after its long run along the dry lake bed and the engineers and technicians come rushing up with trucks and equipment to take plane and pilot and the data both have collected back to the shelter of the Edwards hangar.

In the X-15 program, there's no sudden jump from a low-altitude flight to an extreme one. Each flight is designed to go a little farther in one direction or the other, sometimes higher, sometimes faster, sometimes toward higher temperature conditions. Each step moves toward goals of flight at 100 miles altitude and speeds of over 4,000 mph. Records are not the prime objectives, although they are the most striking parts of the program. The most important thing is to gain more and more data on how man reacts to the extremes of space flight and re-entry, data that will provide the key to designing full-fledged space vehicles that will carry both space pilots and passengers on safe trips to the planets as easily as 600-mph transports make cross-continent hops on earth.

And what of the X-15 after it reaches all its speed-altitude goals? One proposal has been to mate a modified version of it with a rocket booster and use it for an orbital research vehicle or even a space research vehicle to orbit around the moon. One thing is sure. If the X-15 is not used for this, then some other type of manned research craft will perform the mission and at the controls will be such pioneers as Bob White, Joe Walker, Scott Crossfield and the other X-15 veterans or dedicated, experienced men like them.

GLOSSARY

ACQUISITION AND TRACKING RADAR — A radar installation which searches for, locates and tracks an object by means of reflected radio frequency energy from the object, or by means of a radio frequency signal emitted by the object. Continuous position information on the object is provided after the original location of the target.

AERODYNAMICS — The science which treats of the motion of air and other gases, and the forces acting on bodies in motion through air (such as a space ship), or on fixed bodies in a current of air or other gas.

APEX — The highest point of flight.

ASTRONAUT — One who flies or navigates through space.

BALLISTIC TRAJECTORY — The curved portion of a missile's flight after the propulsive force is cut off and the body is acted upon only by gravity, aerodynamic drag, and wind.

BURNOUT — The point in time or in a rocket's trajectory when propellant is exhausted or its flow cut off, resulting in the end of the combustion of fuels in the rocket engine.

CAPSULE — A small, sealed, pressurized cabin where a man or animal may live during extremely high-altitude flights, orbital space flight, or emergency escape.

CENTRIFUGAL FORCE — That force which tends to push a thing outward from a center of rotation.

CENTRIFUGE — A machine using centrifugal force.

CONTROL SURFACE — A movable surface which can be used to deflect an air stream and vary the angle at which an aircraft flies.

COUNTDOWN — The step-by-step process leading to missile launching. It is performed in accordance with a pre-designed time schedule, measured in terms of T−time (T minus time prior to initiation of engine start sequence and T plus time thereafter).

ESCAPE VELOCITY — The speed a body must attain to overcome a gravitational field, such as that of the earth, and thus theoretically travel on to infinity. The velocity of escape at the earth's surface is 36,700 feet per second. A practical manned space craft would travel the atmosphere at a lower velocity and accelerate to escape velocity beyond in order to avoid unacceptable rapid initial acceleration and high skin temperature from aerodynamic heating.

JETTISON — To drop, cast off or away from the plane.

LIQUID OXYGEN — Oxygen supercooled and kept under pressure so that its physical state is liquid. Used as an oxidizer (i.e., to provide oxygen) in a liquid-fuel rocket. Also known as LOX.

ORBIT — The continuously curving path of a body in space in its revolutions around another body; i.e., the path of the moon around the earth.

PROPELLANT — 1) Liquid — Fuel (for example, kerosene) which mixes with an oxidizer (such as liquid oxygen) for power; 2) Solid — A powder compound, containing both fuel and oxidizer, which works like a Fourth of July rocket.

Q-BALL SENSOR — A delicate electronic device in the plane's nose which, by glowing red, reveals the plane's position during re-entry, and transmits data showing the correct position which the ship must take to avoid burning up.

RE-ENTRY — That portion of the flight in which the ship returns from the thinness of near space to the relatively dense atmosphere below.

RE-ENTRY ALTITUDE — The height of the space ship's course at the point where re-entry begins.

SEPARATION — The event which occurs when a stage vehicle is separated from the remainder of the vehicle.

STEP OR STAGE ROCKET — Vehicles consisting of two or more stages; i.e., one smaller rocket mounted on top of another bigger one. Individual stages are dropped after propellants have been burned. Technique is used to obtain maximum speed in a short time.

SIMULATOR — A copy of the cockpit area of a plane, with all the instruments to be used in a real flight hooked up to a computer, which changes the instrument dials as they would be affected by actual flight, while the pilot turns the controls to meet the situation.

ZERO GRAVITY — A condition of weightlessness experienced by a plane and pilot after emerging from the atmosphere of a spatial body such as the earth. It is characterized by floating, or moving continually along a previously directed path or orbit.