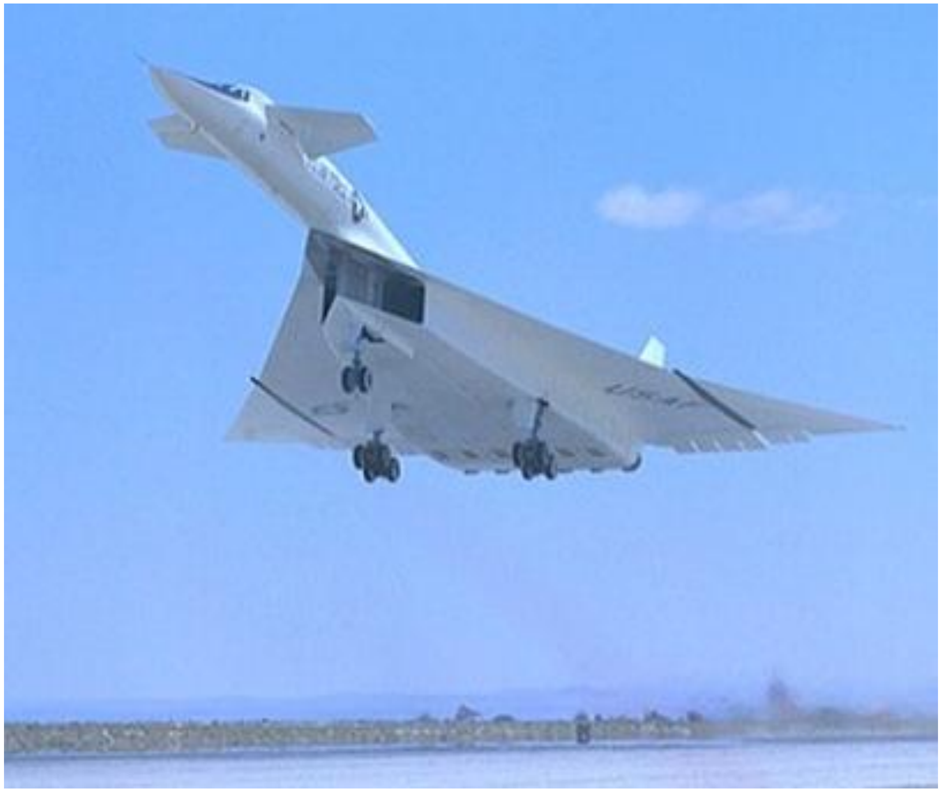
THE XB-70 VALKYRIE STORY



In the 1960's a 10-man crew of electronic engineers and technicians operated the NASA High Range Tracking Station at Beatty, Nevada. Initially, their primary mission was the tracking of X-15 missions originating at Dryden/Edwards AFB in California. When the XB-70 test flights began, NASA's Dryden, Beatty, and Ely tracking stations, along with Air Force, tracked the initial flights originating at Palmdale. It wasn't long before these two magnificent craft were moved to Dryden/Edwards and flown under the management of NASA at Dryden and those contracting for NASA at the Beatty and Ely, Nevada High Range Tracking Stations.

"VALKYRE: Chooser of the slain: Any of the maidens of Odin who choose the heroes to be slain in battle and conduct them to Valhalla."

area51specialproject.com thanks NASA for providing links to the following clips of the Valkyrie taxiing and in flight

Originally conceived as a supersonic bomber, the North American XB-70A Valkyrie instead became the world's largest experimental research aircraft, flying from September 21, 1964, until February 4, 1969.

Two experimental prototypes of the XB-70A were under construction when the bomber program was canceled. At the same time there was growing interest in an American supersonic transport (SST), and the Valkyrie seemed a perfect testbed for SST research. The two prototypes were kept alive for a joint NASA-Air Force flight research program.

The Flight Research Center (FRC -- later the Dryden Flight Research Center) had several SST studies underway in the early 1960's. Its Douglas F5D-1 was used for landing studies, a North American F-100C was modified to simulate SST handling qualities, a North American A-5A was used to develop ways an SST would operate in the air traffic control system, and a Lockheed JetStar was modified as an in-flight SST simulator. But the XB-70A was the first transport-sized aircraft capable of sustained, long-range supersonic flight. Its research programs had a significant impact on American SST efforts at the time and could influence the design of future large, supersonic aircraft.

Although intended to cruise at Mach 3, the first aircraft was found to have poor directional stability above Mach 2.5, and it never flew faster than Mach 2.55 in its flight research at the NASA FRC between 1967 and 1969. However, NASA Ames wind-tunnel studies led North American Aviation, Downey, California, to build its sister ship with an added 5 degrees of dihedral on the wings. It handled much better, and achieved Mach 3.08 on April 12, 1966. Two months later it was lost in a mid-air collision during a formation photo flight.

One of the unique features of the Valkyrie's was the variable outer wing panel. It was left undeflected at subsonic speeds to take advantage of the full wingspan and wing area because that would increase the lift-to-drag ratio and improve takeoff and landing performance.

At supersonic speeds, adequate cruise lift-to-drag ratio could be developed with less wingspan, so the outer panels were folded down. Deflected, they reduced drag as the wingtips interacted with the inlet shock wave in the lower surface flow field. Lowering the wingtips also reduced the area behind the airplane center of gravity (cg). This phenomenon was important because as Mach number increased, the center of pressure moved rearward, so less area aft of the cg caused a reduction of trim drag. The outer panels also provided more vertical surface to improve directional stability.

"The Valkyrie Story"

In 1959, North American Aviation was awarded a contract to build "Weapons System

110" (WS-110). On paper, the project's goals seemed insurmountable; not just the biggest craft ever to take to the skies, but is was to be the fastest as well, to cruise at 3 times the speed of sound, at a time when no plane had yet flown that fast. The original WS-110 competition had boiled down to a competition between Boeing and North American. Although shaped differently, both of the original submissions had the following in common: Takeoff weight of 1,000,000 pounds. Large detachable portion of wing to allow for a Mach 3" dash to target "Mach-3 dash" ability only. They were far too large to use existing USAF facilities designed for the B-52. Needless to say, these proposals were rejected by the USAF, which sent Boeing and North American back to the drawing board. However, during the later phases of the design process, both companies realized that designing an aircraft to actually cruise at mach 3 wasn't really that much more demanding than designing one that only had a "dash" capability. Both teams went back to the drawing boards with what were the final requirements for the contract, which were:

Cruise Speed of Mach 3 (2,000mph)
Cruise Altitude of 70,000 feet.
A "shirtsleeve" environment for the crew.
50,000 pound payload
A range of 7,500 miles

Another requirement called for sizing such that existing runways, hangers, etc. that had already been built for the B-52 could be used without further modification. Have flying characteristics suitable for use with average USAF line crewmen. Boeing's design was essentially very similar to the later SST; that is, essentially a delta with 3 engines (each mounted in its own pod) under each wing.

North American engineers pored through every aerodynamic study they could find ,looking for anything that could be applied to a large, triple sonic bomber. They came across a forgotten NACA (now NASA) research paper about "Compression Lift." This paper described how a conical body underneath the center of awing would push the air to the side, increasing pressure under the wing section (thereby increasing lift!) with far less drag than simply increasing the size of the wing itself. In flight, the XB-70 could lower the outer wing sections either 25 degrees for flying from 300 knots to Mach 1.4, or a severe 65 degrees for speeds from Mach 1.4 to Mach 3+.

Measuring just a bit over 20 feet at the trailing edge, these wingtips represented the largest movable aerodynamic device ever used. Lowering the wingtips had three distinct effects on the XB-70. Total vertical area was increased, allowing shorter vertical stabilizers than would otherwise be needed. The reduction in rearward wing area countered the delta wing's inherent rearward shift of the center of lift as speed increased ,keeping drag-inducing trim corrections to a minimum. Compression lift was30 percent more effective because the shock-wave under the wing was better managed. Along with the wingtips, the six J93 engines, bomb bay, and landing gear were all contained in a conical shape designed to enhance shockwave management. Overall, the XB-70 has the best lift-to-drag ratio of any manned airplane ever built, being bettered only on the unmanned D-21 drone, an airframe designed to be air-launched, fly at one speed and altitude, and then self-destruct (there by not needing to land).

Early (Pre-Flight) History

By 1961, following the shooting down of the U-2 flown by Gary Powers over Russia, it became obvious that the performance of surface-to-air missiles were improving much faster than that of manned aircraft. Following long, loud, and bitter debate, it was decided that the XB-70 would not be a viable bomber platform, and the XB-70 program, as such, was canceled. Development of the F-108 Rapier, intended as a fighter escort to the XB-70, was also canceled. Replacing the production bomber program was a limited program calling for three XB-70 prototypes to perform high-speed flight research. Although this vastly downsized program would have to carry the entire financial burden for the development of the XB-70s radically new construction techniques, as well as the J93 engine, the research data the program would gather would be vitally important for the future SST and other military projects. NASA and the Air Force would jointly manage and share the data garnered from the XB-70.

To help limit costs, a number of non-aerodynamic changes were made to the XB-70. Positions for the navigator and bombardier were removed, leaving the XB-70 with just a pilot and co-pilot. The computerized navigation and bomb-guidance systems were replaced by the bare minimum instrumentation needed to fly safely. In fact, only one TACAN (Tactical Air Navigation) system was installed, which later proved a great annoyance to the XB-70 pilots.

All three XB-70s were intended to be slightly different from each other. The first XB-70 (referred to as AV/1 (AirVehicle/1) or Ship 1) was built entirely from wind tunnel results and initial computer-generated models (at this time, the computer modeling took almost18 months to complete!). AV/2 would be slightly modified based on further computer modeling and early experiences with AV/1. The third airframe, AV/3,would have greater changes based on additional modeling, and extensive flight data gathered from the first two aircraft. The astute observer will notice that the 6' wind tunnel model at the Smithsonian (National Air and Space Museum) is actually of AV/3 (that is, it's a modified version of AV/2 -- note the canard angles).

Constructing the XB-70 required new fabrication techniques, reflecting the production-oriented original design. Extensive use of costly titanium and composite materials would have resulted in a bomber too expensive for mass production, so North American decided to use a stainless steel honeycomb construction -- something that had never been tried before. To keep the weight down, the honeycomb itself was formed of stainless steel just .02" thick! (for perspective, this was the TOLERANCES (variation allowed) in the holes drilled in the frames of WWII fighters to lighten them!) One production manager, after seeing the specifications and being assured they were correct, exclaimed," that's not metal, that's FOIL!" Welding such thin materials was impossible, so a brazing technique had to be developed to assemble the honeycomb structures. Titanium was used in certain heat-critical areas, but overall, the expensive (and difficult to work with) metal makes up only 9 percent of the Valkyrie's structure.

XB-70 number one, with the tail number 20001 (generally referred to as AV/1(Air Vehicle/1) or Ship 1) was rolled out of its hanger at North American's Palmdale, California facility and into the public's view on a bright and sunny May 11th, 1964. Just sitting on the ground, the Valkyrie awed the audience. Her long, graceful neck over their heads, air intakes a man could stand in (and 80' long -- longer than an SR-71!), and sleek lines left no doubt she was designed for speed. But just two months later, the budget axe took its swing, chopping AV/3 (which was in the early stages of construction) out of the program, and, unknowingly, crippled the entire XB-70 program.

Flight History

5:30am, 21 September, 1964 Al White (Chief Test Pilot from North American) and Colonel Joseph Cotton (USAF) begin their pre-flight inspection of the Valkyrie. Today's plan isn't a taxi test, or an engine run-up. White and Cotton will lift the XB-70, the heaviest plane ever built, into the skies above the Mojave Desert and fly from North American's Palmdale facility to Edwards Air Force Base, the Air Force's Flight Test Center (AFFTC). And this is no ordinary flight plan! Once the Valkyrie is over Edwards AFB, it calls for retracting the landing gear, and accelerating the XB-70 beyond the speed of sound at30,000 feet over the desert. In doing so, North American Aviation will receive a $125,000.00 bonus from the Air Force.

At 6:10, White and Cotton climb aboard the Valkyrie to begin the pre-flight checklist. 35 minutes later, engine number one is started and brought up to operating temperatures. Just moments later, in the process of starting engine number two, caution lights go on in the cockpit indicating a failure in the engine's cooling loop. Both engines are shut down, and a few minutes later, the problem is tracked down to a circuit breaker that is reset. The process of starting the engines is begun anew at7:14 and goes off without a hitch.

Finally, with 132,000 pounds (the weight of an SR-71!) of fuel indicated, the XB-70 begins taxiing towards the runway. This is a delicate affair, because the XB-70 has demonstrated a major problem with braking at low speeds (a violent chatter that caused the XB-70s braking distance from just 5mph to be 400 feet!), making maneuvering a tedious affair.

Finally, at 8:24, the Valkyrie is aligned on the runway. Al White advances the six throttles to maximum afterburner, and the XB-70 begins its take off run. At 193 mph, White rotates the long neck of the XB-70 into the air, establishing a nine degree Angle-of-Attack for the wing. At 205 mph and 4,853 feet of runway, the 387,620 pounds of the Valkyrie lifts into the blue sky for the first time. Per the flight plan, speed was held at 310 mph and the gear left down for the flight to Edwards. No unusual handling problems occurred during this time

At 8:51, the XB-70 was over Edwards, and, having met up with all the chase planes involved, Cotton retracts the landing gear. A minute later, waiting for the retraction indicators to go "green," a chase plane calls out that the retraction had failed. The right side main gear had stopped midway through the retraction sequence.

In order to be compact and save space, the XB-70s main landing gear used a complex sequence of motions. From an extended point, the wheel assembly would first rotate 90 degrees (becoming perpendicular to the normal direction of travel). Then, the unit would be rotated 90 degrees vertically, so that rear set of wheels were almost touching the top of the gear's main strut. At this point, the main gear would rotate backward until it was level within the fuselage. Now, however, the right side gear had stopped after only completing the first motion (rotating perpendicular to the direction of flight). The chase plane reported seeing blue streaks on the fuselage behind the gear doors, and that some kind of fluid was continuing to leak out. A leak in the hydraulic system was the suspected culprit, but in mid-flight, the only thing to do was to re-extend the landing gear before a loss of pressure made it impossible to do so. Cycled back to the extended position, the gear locked itself back into place, and the Valkyrie continued on her alternate flight plan, proceeding with some low speed handling tests, which showed stability and control to be more than acceptable -- it was better than the B-52!

Half an hour later, the number three engine was showing 108 percent rpm, and was shut down. White and Cotton then proceeded to line up for landing on the 15,000foot runway at Edwards. Almost 110 feet in front of the landing gear, combined with the nose-up attitude required to land the big delta wing, it was difficult for the pilots to judge their altitude above the runway, or the actual point of touchdown (it was not until the tenth flight that Al White stopped using the chase planes to call out his altitude).

Aiming for touchdown 2,000 feet down the long runway, White smoothly set the XB-70 on the ground. Almost immediately trouble set in. Although White and Cotton couldn't sense it, a pressure surge in the brake system had locked the rear wheels of the left side main gear, causing a fire. Notified of this, White let the Valkyrie coast to a stop, using 10,800 feet of runway. Once the fire was extinguished, repairs had to be made before the XB-70 could be taxied away.

On October 5th, 1964, White and Cotton again took the Valkyrie into the air, again with the intention of achieving supersonic flight (This time, there would be no bonus, but following this flight, North American would be assessed penalties for each additional flight until the XB-70 broke the sound barrier).

Following takeoff, with a chase plane on each side, the landing gear was retracted, then lowered, then retracted again without a problem. With the landing gear up and stowed away, the XB-70 climbed up to 28,000 feet and accelerated to 600mph (Mach .85) in preparation for supersonic flight. Here again gremlins struck the Valkyrie. The primary hydraulic system began losing pressure, and the XB-70 headed back to Edwards. By the time she was on her final approach, the landing gear had to be lowered using the emergency electrical system. The actual touchdown on the lake bed was uneventful, and the XB-70 rolled to a stop after 10,000feet.

A week later, on October 12th, 1964, the Valkyrie burst through the sound barrier for the first time, reaching a speed of Mach 1.1 before decelerating beneath the sound barrier and breaking back through several times to check trans-sonic stability.

October 24th, 1964, represented the Valkyrie's Last flight for a while. Returning to North American's Palmdale facility at The end of this flight, the XB-70 was scheduled to go through a series of Structural tests that would not return her to the flight line until February of 1965.For the first time, the wingtips were lowered to the middle position of 25degrees. Reaching a maximum speed of Mach 1.4, the XB-70 remained supersonic for 40 continuous minutes, establishing a new world's record for sustained supersonic flight. The overall time of the flight was cut short, as fuel consumption proved to be higher than expected.

Upon returning to Palmdale, engineers puzzled over why the Valkyrie had been shedding herself of paint on all but her first flight. Although not overly concerned, no one was especially happy with unexplainable things on a plane that was to test the limits of jet-powered flight! Although some observers wondered if the Air Force was being entirely truthful about the XB-70's top speed, it was finally determined that too-thick paint caused by several re-paintings (in order to pretty the plane up for various VIPs) was being cracked as the Valkyrie flexed in flight, and was then torn away by the air stream. During her winter stay at Plant 42, the XB-70 was carefully repainted with just a single, thin coat of white paint.

AV/1 returned to flight on February 16th,1965. This flight would return the XB-70 to Edwards AFB (about 30 miles by air from North American's Palmdale facility). For the first time, the wingtips were lowered to the full 65 degree mark. Accelerating to Mach 1.6, Joe Cotton then adjusted the AICS (Air Induction Control System)-- The series of ramps inside the intakes which would expand and contract to manipulate airflow to the engines and protect them from the deadly onslaught of high-speed air.

After another 40 minutes of supersonic flight, the Valkyrie landed, but with the drag chutes failing to deploy, the landing run was over11,100 feet. The sixth flight was the first time someone other than Al White and Joseph Cotton were at the controls. Lt. Col. Fitzhugh "Fitz" Fulton (later to be NASA's Chief Test Pilot) flew as copilot with Al White as pilot. But again hydraulic leaks cut this flight short. Engineers at North American worked continuously to modify the hydraulic systems (which operated at 4000psi,more than 35% greater pressure than any other aircraft's system) to end the constant problems of leakage that had disrupted almost every flight. Although these changes were never totally effective on AV/1, AV/2 benefited Greatly from the misfortunes suffered by the first plane.

The seventh flight, on March4th, White and Fulton shattered records again, sustaining supersonic flight for 60 minutes, reaching a top speed of Mach 1.85. The eighth flight introduced the last of the four pilots, North American's Van Shepard, to the aircraft, and saw Mach 2 fall to the six J93 engines.

On the tenth flight, the Valkyrie sustained 74 minutes of supersonic flight, including 50 minutes beyond Mach2! May 7th, 1965 was AV/1's 12th flight, with Al White and Fitz Fulton at the controls. Traveling at Mach 2.58 (almost 1700mph!), a 'thump' was heard in the cockpit, soon followed by a number engine-related alarms. Engines three, four, five, and six were shut down right away. As the chase planes caught up, they reported that the horizontal splitter (the very apex of the delta wing) had torn away. Obviously, the debris had gone into the intakes and done severe damage to the engines. For the final approach, the number five engine was restarted to provide some thrust from the right side, and the XB-70 landed on the long lakebed without major incident. All six engines, nearly one-sixth of the 38 ever built, were destroyed beyond repair.

After this flight, the splitter itself was replaced with a single solid piece in place of the honeycomb unit that had failed. At this point, concerns about the integrity of the honeycomb skin began, and the next 4 flights concerned themselves with "heat soaking" the skin for sustained periods of time. For the first time, the XB-70s ability to reach Mach 3 was questioned.

AV/2 (tail number 20207) made its first flight on July 17th, 1965. Lacking the gremlins of AV/1's first flight, the wingtips were lowered 65 degrees, and a top speed of Mach 1.4 was reached before landing at Edwards AFB. AV/2 differed from her older sibling, inside and out.

Internally, a more flexible system of hydraulic fittings were used, to reduce the leaking that continued to trouble AV/1. The techniques to build the honeycomb skin and improved with experience, and hopefully would not suffer any of the troubles AV/1 was undergoing. Learning from experience, the fuel tanks on AV/2 were inspected very carefully, to avoid the internal leakage problems which ultimately rendered AV/1's number five (centerline fuselage) unusable. An automatic control for the AICS was installed, in place of AV/1's manual system, which used a grid of speed and altitude that the pilots used as a reference to set the actual ramp position.

Externally, the difference was obvious -- the Wings had been given 5 degrees of dihedral. This change was a result of testing that showed AV/1 to have poor roll stability at high speed with the wingtips fully lowered. The trade off was that, at low speeds with the wingtips up, AV/2 suffered from severe "dihedral effect" -- a situation where sideslip causes the plane to drop one wing. The pilot, sensing the low wing but not spotting the sideslip, would use the ailerons to try and bring the wing back up -- which actually caused MORE sideslip, forcing the wing to drop lower! One pilot remarked "it felt like being backed into a corner." The only solution was for pilots to closely watch the side slip indicator.

Another instrumentation problem cropped up during high-speed flight. At Mach 3, just one degree of pitch would send the XB-70 into a 3,000 foot per minute change of altitude. Combined with raising the nose ramp (windscreen assembly) to the "supersonic" position, which blocked the pilots' view of the horizon (and tended to reflect the ground below, leading to several complaints of vertigo), the Valkyrie was virtually impossible to keep at a fixed altitude. Eventually, a highly sensitive rate-of-climb meter from a helicopter was Installed to help (but not entirely fix) this problem.

October 14th, 1965. "On this flight the XB-70 proved its capability of attaining Mach 3 at 70,000 feet!"-- Al White's summary in the pilot's report for Flight 1-17.

As AV/1 crossed the Mach 3threshold, her nose abruptly pitched upwards. But even as Al White corrected, the nose just as sharply pitched downward. Combined with the correction, the XB-70 accelerated just enough to cause a brief moment of overpressure in the inlets. Stabilizing the Valkyrie, Al White keyed his microphone and spoke the words everyone had been waiting for, "There's that big magic number [Mach 3]."

For almost three minutes, everything appeared fine. Suddenly, White and Cotton heard something behind them. Although no caution lights had come on, and concerned about damage caused by the overpressure, White decided to decelerate and let the chase planes catch up with the XB-70. When they did, they reported that about 2 feet of the left wing's leading Edge was missing. Fortunately, the damaged section of the wing was far enough outboard that the debris wasn't drawn into the engine inlets. After 56 weeks and 17 flights, AV/1 had finally reached her goals -- but she would never fly at Mach 3 again.

The design team, alarmed with the skin separation problems, and knowing that improvements in AV/2 would solve the problem, decided that from that point on, AV/1 would be limited to a maximum speed of Mach 2.5. Mach 3 research would be left to the improved, and more capable, second aircraft.

Initially, AV/2 (tail number 20207) wasn't completely trouble-free. Brake chatter continued to be a problem during low-speed taxiing, although it was suspected that this stemmed from the lack of return springs for the brake pads (like automobiles, the Valkyrie was designed for the pads to lightly touch the rotors at all times). Far more troubling, however, were problems in the new, automatic AICS system, which would inexplicably recycle during supersonic flight, causing an "unstart," where the shockwave from the forward fuselage, rather than being deflected past the inlet and under the wing, instead fell directly into the inlet. Not only did this change in inlet airflow cause a brief flameout on the engines, but it also caused a dramatic loss of lift on that side, since the XB-70s wings depended on that high-pressure air for a large portion of their lift. Some times, speed and throat ramp settings would create a condition where the shockwave was right at the boundary of the inlet, jumping in and out. This "buzz" was a serious condition that had to be rectified immediately-- left to continue for more than a few moments, the stresses could have torn the XB-70 apart!

Following the 8th flight of AV/2, White stated in his pilot's report that he didn't feel comfortable trying for Mach 3 until the AICS was sorted out, which took several additional flights. As this was sorted out, concerns were voiced that AV/2 might also suffer skin separation problems under the heating caused by sustained high-speed flight, despite the improved construction and assembly techniques. It was decided that with AV/2, early flights would involve "heat-soaking" at speeds less than Mach 3. This way unlike a quicker "dash" up to speed, the airframe would reach the full temperature created by flight at that speed.

Heat is the major enemy of speed. Caused by the friction of cutting through the air, heat has limited the top speed of modern aircraft (such as the F-15) far more than power. Beyond Mach 2.5,friction increases at an ever-growing rate (for comparison, an SR-71 operating at Mach 2.2 heats up to about 275 degrees, but at Mach 3.2, skin temperatures rise to almost 900 degrees!).

The same aerodynamics that gave the XB-70 so little drag helped minimize heat buildup. The hottest portions of the Valkyrie, her nose and horizontal splitter, reached a temperature of only 625 degrees during Mach 3 flight, with the majority of the XB-70s skin at a temperature of just 450 degrees! Equipment was placed in the fuel tanks, which acted as heat sinks. As the fuel soaked up the heat from the fuselage, it was drawn into the engines and burned away, leaving the cooler fuel behind. At the same time, it had to be replaced with nitrogen gas. The temperatures inside the tanks were high enough that just two percent oxygen would have caused the fuel to burst into flames -- a decidedly undesirable event.

On her 15th flight, on December 11th, 1965, AV/2 ran at Mach 2.8 for20 minutes (spending 41 total minutes beyond Mach 2.5) without any indications of skin separation. Ten days later, after seven minutes at Mach 2.9 (and 20 minutes above Mach 2.8), the oil pump for the number four engine failed, shutting down the engine, White and Cotton headed back to Edwards, when an over temperature caution came on for the number six engine, which was shut down as well. After landing, it was discovered that, despite the early shutdown, loss of lubrication had ruined engine number four -- an unhappy moment in a flight program that now only had 29 engines left (with 12 needed just to get the two planes in the air!). The number six engine was removed and sent off to General Electric for rebuilding.

Engine installation was another ground-breaking feature of the XB-70. Unlike other airplanes, where all the engine's accessories were bolted to the plane, and then connected to the engine (making removal a tedious job), on the Valkyrie, everything was bolted to the engine itself, making engine removal and replacement a job that could be done in just a couple of hours. Today, many military and commercial planes use this design.

Less than 6 months after her first flight, AV/2 reached her goal of Mach 3, on her 17th flight (coincidently, the same number of flights AV/1 to reach Mach 3). Just for three minutes, then back home for a through examination. No sign of skin damage at all! Prudence was still the watchword, however, and AV/2 twice more poked her sleek nose beyond Mach 3 for just a few minutes before sustaining Mach 3 for 15 minutes on her 22nd flight.

Feeling secure that AV/2 would not have the same skin separation problems of AV/1, extensive performance and control testing at speeds above Mach 2.7, but below Mach3 were the next step. This data was important for determining what the handling abilities of the SST (intended to cruise at around Mach 2.7) would be like.

Already, it had become obvious that no SST could be expected to use the established approach routes to airports! Some sonic boom testing (although not as extensive as later on) was also conducted. The viability of the SST depended on high-altitude sonic booms being greatly dissipated as compared to lower altitude sonic boom effects.

To the dismay of many, early tests indicated this would not be the case. At this point in March, 1966, AV/1 was getting ready for her 37th flight, with Van Shepard as pilot, and Joseph Cotton as co-pilot. Control and performance tests were on the flight plan -- but soon it was a different performance being tested.

Halfway through the planned flight, BOTH hydraulic systems -- primary and secondary -- began to fail. Shepard quickly brought the Valkyrie home as Cotton extended the landing gear. No green indicators came on, followed by a call from the chase plane that there was trouble with both sets of main gear. On the left side, the gear hadn't fully lowered before rotating to meet the direction of travel, leaving her rear wheels higher, rather than lower, than the front set of wheels. The right side gear was in worse shape -- it hadn't lowered at all before rotating. Even more alarming, it hadn't rotated completely inline with the direction of travel, although it was close.

The emergency backup system failed to correct the problem, and with overall control of the aircraft rapidly coming into question, engineers on the ground had to think quickly, or face losing an aircraft that was a half-billion dollar investment. After what must have seemed like hours in the cockpit, engineers on the ground called up to the pilots with their plan. Shepard would land the Valkyrie on the dry lake bed, so there would be plenty of room to ease to a stop. It was felt that, on touchdown, the left side gear would level itself out, the sheer weight of the XB-70 forcing the gear into its normal position. As for the right gear...being behind the centerline of the main strut, it was unlikely that the gear would level out, but hopefully the landing would at least cause the gear to finish swinging into the direction of travel, and the wingtip would still clear the ground, although the right side would be much lower than the left.

Van Shepard gingerly set AV/1 down on the lakebed, and each main gear did what the engineers expected. So now, the plane was down and rolling, but she wanted to turn sharply to the right-- threatening to ground loop, which, although likely not fatal to the pilots, would likely destroy the aircraft. So Shepard kept applying power to the number six (farthest right side) engine to help keep the XB-70 somewhat straight, but at the same time, he couldn't use too much power, or the plane wouldn't ever stop! Finally, after rolling almost three miles, the XB-70 completed her landing run, which, when viewed from above, looked like an upside-down letter "J" because the XB-70 had not just swung over half a mile to the right side, but by the time she came to a stop, she had turned 110 degrees, almost pointing in the direction she had come from! Only the huge size of the lakebed made this landing possible --anywhere else, the XB-70 would have been far off the runway and likely into buildings and hangars (another decidedly undesirable event).

Later that same month, to the joy of a great many Texans, it was decided that AV/2 would be flown down to Carswell AFB for the air show there. It was to be the only airfield that Ship Two would fly to and return. With Fitz Fulton at the controls, the Valkyrie spent only 13 minutes at Mach 2.6 before slowing up, winding up at 6,000 feet over Carswell AFB just 59 minutes after takeoff! For the next half hour, AV/2 thundered around the skies of Texas before landing. The return flight two days later was the only flight during the entire program where performance data was not recorded, as Cotton (in the pilot's seat) and White flew back at subsonic speeds, taking a little over three hours to return to Edwards. Then AV/2 was off to heat soak for even longer times -- over 30 minutes-- at speeds of Mach 2.8 and 2.9, as well as flights of 16 and 20 minutes at Mach 3. Flights 35 and 36 were used to get a better look at the causes and ways to remedy unstarts at speeds above Mach 2.5.

April 30th, 1966. Al White and Joe Cotton prepared to take AV/2 past the final hurdle to having" unlimited" status for Mach 3 flight-- a 30+ minute run at Mach 3 to fully heat soak all systems. Shortly after takeoff, Cotton retracted the landing gear. The nose gear jammed into its door, and as good as things had been going, they were going bad now. The attempt to lower the gear using the normal hydraulic system failed. Trying the backup electrical system, Cotton heard a "pop" as THAT system went dead. Given the Valkyrie's long, graceful neck, and the intake design, retracting the main gear and landing on her belly wasn't possible-- in fact, it was so impossible that North American had never attempted to simulate it!

White first brought the XB-70 around for a touch-and-go, Hoping that a hard impact on the main gear would knock the nose gear loose and let it fall to the extended position. Even after a second try, however, the nose gear remained jammed. At this point, bailing out and losing the aircraft was quickly becoming the only option. But there was fuel to burn away in any case, so while people on the ground pulled out plans and diagrams, White and Cotton circled around Edwards slowly but surely. Finally, Cotton was sent to the back of the cockpit to open service panels and check on things for the people below. After more than an hour of this (and 2 hours of flying), the problem with the backup system was traced -- hopefully -- to a circuit breaker. Now all Cotton had to do was find a way to short circuit the unit by closing two contacts. Of course, the Valkyrie had no on-board toolkit -- that would have made things too simple. But Cotton HAD brought along his briefcase with his various notes and plans, and opening it, he found a good, thick paperclip. Straightening out the paperclip, then grasping the middle of it with a leather glove, Cotton carefully reached in and ZAP! short circuited the breaker.

As Al White hit the switch to extend the gear, and was rewarded with the sound of a working backup system, Cotton gratefully dropped into his seat. As several newspapers exclaimed the following day, a "39 cent paperclip saves $750 million aircraft!" And indeed it had. In the landing, however, the main gear bogies had been damaged, and would take two weeks to repair -- although this was a tiny price compared to losing the aircraft.

Unbeknownst to everyone involved, the loss of the AV/2 wasn't avoided, but merely postponed a little longer. Finally, on May 19th, flight number 39, AV/2 flew at Mach 3 for 33 minutes, and a total of 62 minutes beyond Mach 2.5. In just 91 minutes, the Valkyrie traveled over 2,400 miles -- an average speed of more than 1500 miles per hour, including takeoff and landing! Finally, all remaining concerns about skin separation were laid to rest.

Listening to the VHF and UHF radios at the Beatty Tracking Station, it seemed that every mission the chase planes would report a loose object flying off the massive plane. Being located central along the normal flight path for the X-15 and XB-70, a straight line from Wendover, Utah to Edwards AFB, our radar sight usually carried the load of tracking these flights. Even though the aircraft transmitted a thousand watt beacon each time one of our radars interrogated the transponder, neither Edwards or the Ely radar could track either plane. I vividly recall a mission where the XB-70 was to conduct a Mach3+ speed run. Neither the T33 or F104 chase planes were capable of these speeds, which meant the Valkyrie was going to run away from its chase planes. (During a normal mission, these chase planes would actually maneuver around the much larger plane to visually inspect it for any anomalies.) The mission went well, the Valkyrie outrunning its chases. The plane had turned to head back to Edwards and its chase escort when all of a sudden Cotton announced loss of engines. My crew at Beatty were the only ones tracking the plane's beacon as it starting losing altitude over Mt. Charleston near Las Vegas, Nevada. Suddenly, the Valkyrie lost auxiliary electrical power, causing the beacon return to disappear from our radar scopes and loss of radio contact.. Skin track of the plane was sketchy, but from all indications, the plane was going to crash into Mt. Charleston. At a mere 500 feet altitude above the highest peak, the beacon suddenly reappeared and Cotton's cheerful voice filled our speakers as he announced restart of his engines. The chase planes located the plane and escorted it safely home to Edwards.

The improved methods used to build AV/2were more than up to the task of sustained Mach 3 flight. After this, AV/2flew to test stability and control at subsonic and supersonic speeds. On May 22nd, 1966, AV/2 thrilled the spectators at the Armed Forces Day show at Edwards, including a couple of supersonic passes over the crowd. At this point, with all systems tested, the XB-70 program prepared to move into Phase 2, where NASA would become much more involved, and extensive sonic boom and handling tests would begin. New pilots would join the program, including NASA Chief Test Pilot Brigadier General Joe Walker, who had just wound down the X-15 program.

Not only did Walker have an "astronaut" rating (given to any pilot who flew higher than 50 miles, which the X-15 did), he had flown the X-15 beyond Mach 6 (4,100mph) in level flight (a later flight by Pete Knight with external tanks did more then 4,500mph). Also joining the program was USAF Major Carl Cross. At the same time, both Al White and Joseph Cotton would gradually ease out of the program, with Cotton going on to test newer planes for the Air Force, and White to work on other projects at North American.

The Valkyrie had reached her goals, and been tested successfully. Al White had achieved his goals for the XB-70 program. In preparation for Phase 2, AV/2 was refitted with even more data recording equipment, costing more than $50 million. These instruments would give a better look at a number of phenomena that couldn't be thoroughly tested in a wind tunnel - information regarding body flex, flutter, and pressure. At the same time, NASA began setting up a large number of ground sensors to precisely measure the effect of sonic booms.

"Midair! Midair! Midair!"

June 8th, 1966. Major Carl Cross sits in the Valkyrie's cockpit for the first time, with Al

White in the pilot's seat. Their flight plan is simple: they will make several passes over recording instruments at a speed of Mach 1.4 at 32,000 feet, then, at the request of General Electric, they will fly in formation with 4 other GE-powered aircraft so that GE photographers can take some publicity pictures. The boom-testing went smoothly, then, dropping subsonic speed and raising the wingtips back to 25 degrees, the Valkyrie joined up in formation with the other aircraft, including, just off her right wingtip, an F-104 Starfighter piloted by Joe Walker. As the photo shoot progressed, the photographers asked several times for the formation to close up, until all five planes were in close proximity, and had been for over 45 minutes.

(Author's note: At the Beatty tracking station we routinely recorded the communications channel on a Fisher tape recorder. Only moments before the Mid-air Joe Walker officially notified mission control that he was encountering turbulence. He further stated for the record that he opposed this mission as it was too dangerous and had no scientific value. [The purpose of the mission was to provide General Electric, the manufacturer of the engines for the planes in formation, a photo for the cover of their brochures to be presented at an upcoming shareholders' meeting] Immediately after the crash, Mr. Bill Houck, the NASA monitor at our station, requested I give him the tape for dispatch to NASA at Dryden.)

Finally, at 9:26am, the photographers were done, and everyone prepared to break formation and return to Edwards. Disaster struck at this moment as somehow, Walker's F-104 collided with the Valkyrie. The complex airflow surrounding the XB-70 lifted the F-104 over her back ,spun the Starfighter around 180 degrees, causing it to smash down along the center of the Valkyrie's wing, tearing off both vertical stabilizers and damaging the left wingtip before falling away in flames. Already, Joseph A. Walker, one of America's greatest pilots, was dead.

"Midair! Midair! Midair!" Al White and Carl Cross heard the impact, but felt nothing. Flying in theT-38 Off the left wingtip, Joe Cotton called out "207 (identifying AV/2) you've been hit! You've been hit!" But in those first moments, neither White nor Cross heard the call. Even as Cotton continued "okay, you're doing fine, he got the verticals, but you're still doing fine," White turned to Cross and asked "I wonder who got hit?" Sixteen seconds after the impact, the XB-70 started a slight roll. Al White corrected the roll -- and instantly recognized the Valkyrie's peril as she began a snap roll to the right.

Ramming the number six engine's throttle to maximum afterburner, he tried to save AV/2 - but after 2 slow rolls, the plane broke into a sickening spin, taking any hopes of recovery with it. White pushed his seat back into the eject position, but caught his arm in the ejection pod's clamshell doors as they closed. Unable to communicate with the struggling Carl Cross, and unable to eject until getting his arm clear, White could only watch his co-pilot fail to get into his pod for ejection. Finally, with the realization that he needed to get out now, Al White worked his arm clear and ejected just moments before AV/2 slammed into the ground a few miles north of Barstow, California. Although the drogue chutes deployed from White's pod, he realized the airbag underneath the pod-- designed to absorb much of the impact -- had failed to inflate.

Striking the ground, White took a 44G impact -- lessened to 33Gs as his chair broke free of its mountings. Amazingly, although banged, battered, and bruised, he suffered no broken bones. Although White returned to flight status just three months later, he never flew the XB-70 again.

Carl Cross was not so lucky. Still in his seat, he impacted the ground with AV/2 in a relatively flat configuration and was killed instantly. In just 76 seconds, 2 men, and one of the greatest planes ever built were gone.

The Final Flights

Following the crash and subsequent investigation, which blamed several people for allowing the "unofficial" photo shoot, several key modifications were made to AV/1. Amongst the important changes were modifications to the ejection system to make it easier, and the installation of modified brakes to allow for return springs for the brake pads. Unsurprisingly, the brake modification cured the problem of brake chatter at low speeds. The instrumentation package was upgraded to a system similar to the package installed on AV/2.

Both the USAF and NASA were unsure that AV/1, with her Mach 2.5 speed limitation and general gremlin troubles, could perform the research intended for AV/2. Ultimately, after a few more flights, the Air Force bowed out of the XB-70 program, leaving NASA to carry on additional flights on its own. Although not doing as well as AV/2 would have, the older Valkyrie soldiered on for 33 additional flights, garnering valuable data about high-speed flight. Finally, on February 4th,1969, AV/1 took off for her eighty-second, and final flight, to the Air Force Museum at Wright Field, in Dayton, Ohio.

Gathering data throughout the entire flight, Fitz Fulton made a pass over the runway before bringing the XB-70 down for a perfect landing, then, handing the logbook to the museum curator, officially ended the XB-70 program.

Today, the Valkyrie resides inside the recently built Modern Aviation hanger, finally protected from the ravages of time. Summary Some have looked at the XB-70 program, pointed out that the expenditure of $1.3 billion only resulted in 128 flights and one high-maintenance aircraft at the USAF Museum. Others have pointed to the YF-12 and SR-71 as far more successful and capable testbeds for Mach 3 flight.

But the Valkyrie was more than just an airplane. It was a complete package that advanced aerodynamic design, created the template for honeycomb construction, and allowed for extensive testing almost a decade before the first SR-71 appeared at an air show. In addition, the YF-12 and SR-71 were never destined for mass production--their cost was far too high with the composite and titanium skin, and maintenance costs off the charts (In 1991, with just a few airframes in service, the USAF still spent more than $400 million on maintaining the Blackbird). Much of the costs related to the XB-70 would have easily been amortized out had production ever become a reality. The J93 engines, the tooling to build the airframes -- all of this normally would have been spread across hundreds of aircraft. Indeed, indirectly, the research from the program went on to benefit many aircraft, from supersonic fighters to mundane commercial jetliners.

Had AV/2 not been lost, there would certainly have been many, many more flights. But even with the limited flights, and the use of AV/1 at the end of the program, critical data regarding the SST was gained. Even though we don't think about it, the Valkyrie effectively killed the SST program by showing that supersonic flight by airliners, no matter how high they flew, would have too great a sonic boom at ground level to ever be acceptable.

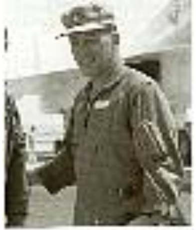
Modern test programs have involved high angles of attack, improved control, and many other features important to the planes of tomorrow. But unlike the Valkyrie, they represent advances into the known, enhancements of what aircraft are capable of today. The Valkyrie was conceived in 1959,a year when the Air Force was getting its first Mach 2 fighter (ironically, the F-104 Starfighter), yet here was a program calling for a Mach 3 bomber with long-range endurance. And despite never being truly optimized from flight data, the program developed a plane that could take off weighing more than 538,000 pounds, and cruise at three times the speed of sound. The magic of the Valkyrie is not just in what she accomplished, but in how far she reached to accomplish it.

Compared with the technology today, those of us responsible for the tracking, communication, telemetry, and instrumentation of the XB-70 flights (and those of the X-15, SR-71, and Lifting Bodies) were operating with equipment barely out of the stone age. Our radar systems were 1940's Mod-2 systems scrapped at Cape Canaveral and passed on to Edwards. Merely pulling a chassis caused wiring installation to crumble to the floor, exposing the bare wire.

Originally designed for a maximum range of about 80 miles, the systems had been modified for extended range. Locking on a thousand-watt beacon made it possible to track the XB-70 for hundreds of miles. Many a time I witnessed the return spike reaching the end of the base-line of the radar scope only to reappear at the start of baseline as the range of the craft being tracked moved further away. Somehow, we always managed to bring our test pilots home.

I'll never forget hearing the gut-wrenching "Midair, Midair" distress call while sitting at my console at the Beatty Tracking Station. In a state of disbelief, I listened to the mission audio recording five times before placing it in the overnight dispatch to NASA at Dryden. I didn't personally know Carl Cross as I did General Joe Walker and Colonel Joseph Cotton. It saddens me still to think that Carl and Joe gave their lives merely to provide General Electric with a neat photograph to place on the cover of a corporate brochure. For no scientific reason whatsoever, we lost two brave test pilots and aerospace program that would have launched our nation into the 21st century sixty years before its time.

THE VALKYRIE PILOTS



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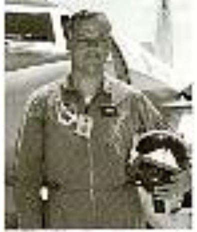
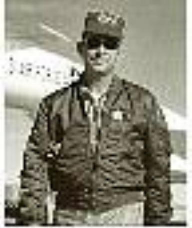


Major Carl S. Cross



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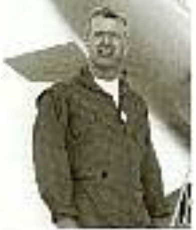

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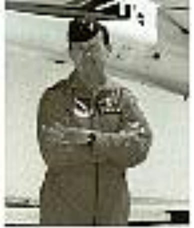
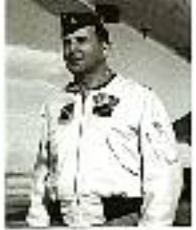


Colonel Joseph F. [illegible]



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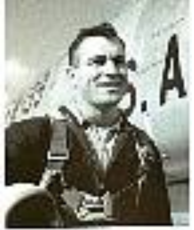

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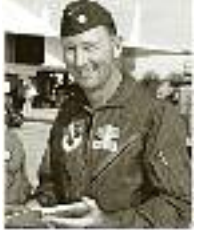

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