  

SR-71 Blackbird

The Lockheed SR-71 is an advanced, long-range, Mach 3 strategic reconnaissance aircraft developed from the Lockheed A-12 and YF-12A aircraft by the Lockheed Skunk Works as a Black project. The SR-71 was unofficially named the Blackbird, and called the Habu by its crews, referring to an Okinawan species of pit viper. Clarence "Kelly" Johnson was responsible for many of the design's innovative concepts. A defensive feature of the aircraft was its high speed and operating altitude, whereby, if a surface-to-air missile launch were detected, standard evasive action was simply to accelerate. The SR-71 line was in service from 1964 to 1998, with 12 of the 32 aircraft being destroyed in accidents, though none were lost to enemy action.

Development

Predecessors

The A-12 OXCART, designed for the CIA by Clarence Johnson at the Lockheed Skunk Works, was the precursor of the SR-71. Lockheed used the name "Archangel" for this design, but many documents use Johnson's preferred name for the aircraft, "the Article". As the design evolved, the internal Lockheed designation progressed from A-1 to A-12 as configuration changes occurred, such as substantial design changes to reduce the radar cross-section.

The first flight, by an A-12 known as "Article 121", took place at Groom Lake (Area 51), Nevada, on 25 April 1962 equipped with the less powerful Pratt & Whitney J75 engines due to protracted development of the intended Pratt & Whitney J58. The J58s were retrofitted as they became available, and became the standard power plant for all subsequent aircraft in the series (A-12, YF-12, M-21) as well as the follow-on SR-71 aircraft.

Eighteen A-12 family aircraft were built. One was a pilot trainer with a raised second cockpit for an Instructor-Pilot and 12 were reconnaissance A-12s to be flown operationally by CIA pilots. Three were YF-12A prototypes of the planned F-12B interceptor version, and two were the M-21 variant.

SR-71

The SR-71 designator is a continuation of the pre-1962 bomber series, which ended with the XB-70 Valkyrie. During the later period of its testing, the B-70 was proposed for a reconnaissance/strike role, with an RS-70 designation. When it was clear that the A-12 performance potential was much greater, the Air Force ordered a variant of the A-12 in December 1962. Originally named R-12, the Air Force version was longer and heavier than the A-12. Its fuselage was lengthened for additional fuel capacity to increase range. Its cockpit included a second seat and the chines were reshaped. Reconnaissance equipment included signals intelligence sensors, a side-looking radar and a photo camera. The CIA's A-12 remained a better reconnaissance platform than the Air Force's R-12, however, especially since the A-12 flew higher and faster[7] and with only one pilot it had room to carry a superior camera and more instruments.

During the 1964 campaign, Republican presidential nominee Barry Goldwater continually criticized President Lyndon B. Johnson and his administration for falling behind the Soviet Union in the research and development of new weapons systems. Johnson decided to counter this criticism by announcing the YF-12A Air Force interceptor (which also served as cover for the still-secret A-12) and, on 25 July 1964, the Air Force reconnaissance model. Air Force Chief of Staff General Curtis LeMay preferred the SR (Strategic Reconnaissance) designation and wanted the RS-71 to be named SR-71. Before the July speech, LeMay lobbied to modify Johnson's speech to read SR-71 instead of RS-71. The media transcript given to the press at the time still had the earlier RS-71 designation in places, creating the myth that the president had misread the aircraft's designation.

This public disclosure of the program and its renaming came as a shock to everyone at the Skunk Works and to Air Force personnel involved in the program. All of the printed maintenance manuals, flight crew handbooks, training slides and materials were labeled "R-12" and the 18 June 1965 Certificates of Completion issued by the Skunk Works to the first Air Force Flight Crews and their Wing Commander were labeled "R-12 Flight Crew Systems Indoctrination, Course VIII". Following Johnson's speech the name change was taken as an order from the Commander-in-Chief, and immediate reprinting began of new materials, including 29,000 blueprints, to be retitled "SR-71"

Design and operational details

A particularly difficult issue with flight at over Mach 3 is the high temperatures generated. As an aircraft moves through the air at supersonic speed, the air in front of the aircraft is compressed into a supersonic shock wave, and the energy generated by this heats the airframe. To address this problem, high-temperature materials were needed, and the airframe of the SR-71 was substantially made of titanium, obtained from the USSR at the height of the Cold War. Lockheed used many guises to prevent the Soviet government from knowing what the titanium was to be used for. In order to control costs, Lockheed used a more easily-worked alloy of titanium which softened at a lower temperature. Finished aircraft were painted a dark blue (almost black) to increase the emission of internal heat (since fuel was used as a heat sink for avionics cooling) and to act as camouflage against the night sky. The aircraft was designed to minimize its radar cross-section, an early attempt at stealth design. The call sign of the aircraft, "Blackbird", signifies the resistance of its airframe to visible light and radar detection.

Air inlets

The air inlets were a critical design feature that allowed cruising speeds of over Mach 3.2, and yet at the same time could maintain subsonic Mach 0.5 airflow into the turbojet engines. At the front of each inlet was a sharp, pointed movable cone called a "spike" that was locked in the full forward position on the ground or when in subsonic flight. During acceleration to high-speed cruise, the spike would unlock at Mach 1.6 and then begin a mechanical (internal jackscrew powered) travel to the rear. It moved up to a maximum of 26 inches (66 cm).

The original air inlet computer was an analog design which, based on pitot-static, pitch, roll, yaw, and angle-of-attack inputs, would determine how much movement was required. By moving, the spike tip would withdraw the shock wave, riding on it closer to the inlet cowling until it just touched slightly inside the cowling lip. In this position shock-wave spillage, causing turbulence over the outer nacelle and wing, was minimized while the spike shock-wave then repeatedly reflected between the spike

centerbody and the inlet inner cowl sides. In doing so, shock pressures were maintained while slowing the air until a Mach 1 shock wave formed in front of the engine compressor.

The backside of this "normal" shock wave was subsonic air for ingestion into the engine compressor. Tremendous pressures would be built up inside the inlet and in front of the compressor face. Bleed tubes and bypass doors were designed into the inlet and engine nacelles to handle some of this pressure and to position the final shock to allow the inlet to remain "started." It is commonly cited that a large amount of the thrust at higher mach numbers comes from the inlet. However, this is not entirely accurate. Air that is compressed by the inlet/shockwave interaction is diverted around the turbo machinery of the engine and directly into the afterburner where it is mixed and burned. This configuration is essentially a ramjet and provides up to 70% of the aircraft's thrust at higher mach numbers.

Ben Rich, the Lockheed Skunkworks designer of the inlets, often referred to the engine compressors as "pumps to keep the inlets alive" and sized the inlets for Mach 3.2 cruise (where the aircraft was at its most efficient design point). The additional "thrust" refers to the reduction of engine energy required to compress the airflow. One unique characteristic of the SR-71 is that the faster it went, the more fuel-efficient it was in terms of pounds burned per nautical mile traveled. An incident related by Brian Shul, author of Sled Driver: Flying the World's Fastest Jet, was that on one reconnaissance run he was fired upon several times. In accordance with procedure they accelerated and maintained the higher than normal velocity for some time; afterwards they discovered that this had reduced their fuel consumption.

In the early years of the Blackbird programs the analog air inlet computers would not always keep up with rapidly-changing flight environmental inputs. If internal pressures became too great and the spike was incorrectly positioned the shock wave would suddenly blow out the front of the inlet, called an "Inlet Unstart." The flow of air through the engine compressor would immediately stop, thrust would drop, and exhaust gas temperatures would begin to rise. Due to the tremendous thrust of the remaining engine pushing the aircraft asymmetrically an unstart would cause the aircraft to yaw violently to one side. SAS, autopilot, and manual control inputs would fight the yawing, but often the extreme off-angle would reduce airflow in the opposite engine and cause it to begin "sympathetic stalls." The result would be rapid counter-yawing, often loud "banging" noises and a rough ride. The crews' pressure-suit helmets would sometimes bang on the cockpit canopies until the initial unstart motions subsided.

One of the standard counters to an inlet unstart was for the pilot to reach out and unstart both inlets; this drove both spikes out, stopped the yawing conditions and allowed the pilot to restart each inlet. Once restarted, with normal engine combustion, the plane could accelerate and climb to the planned cruise altitude.

The analog air inlet computer was later replaced by a digital one. Lockheed engineers developed control software for the engine inlets that would recapture the lost shock wave and re-light the engine before the pilot was aware an unstart had occurred. Precise positioning of the forward air by-pass doors within the inlets helped control the shock wave, prevent unstarts, and increase performance.

Fuselage

To allow for thermal expansion at the high operational temperatures the fuselage panels were manufactured to fit only loosely on the ground. Proper alignment was only achieved when the airframe heated due to air resistance at high speeds, causing the airframe to expand several inches. Because of this, and the lack of a fuel sealing system that could handle the thermal expansion of the airframe at extreme temperatures, the aircraft would leak JP-7 jet fuel onto the runway before it took off. The aircraft would quickly make a short sprint, meant to warm up the airframe, and was then refueled in the air before departing on its mission. Cooling was carried out by cycling fuel behind the titanium surfaces at the front of the wings (chines). On landing after a mission the canopy temperature was over 300 °C (572 °F), too hot to approach. Non-fibrous asbestos with high heat tolerance was used in high-temperature areas.

Stealth

There were a number of features in the SR-71 that were designed to reduce its radar signature. The first studies in radar stealth technology seemed to indicate that a shape with flattened, tapering sides would avoid reflecting most radar energy toward the radar beams' place of origin. To this end, the radar engineers suggested adding chines (see below) to the design and canting the vertical control surfaces inward. The aircraft also used special radar-absorbing materials which were incorporated into sawtooth shaped sections of the skin of the aircraft, as well as cesium-based fuel additives toreduce the exhaust plumes' visibility on radar.

The overall effectiveness of these designs is still debated; Ben Rich's team could show that the radar return was, in fact, reduced, but Kelly Johnson later conceded that Russian radar technology was advancing faster than the "anti-radar" technology

Lockheed was using to counter it.[18] The SR-71 made its debut years before Pyotr Ya. Ufimtsev's ground-breaking research made possible today's stealth technologies, and, despite Lockheed's best efforts, the SR-71 was still easy to track by radar and had a huge infrared signature when cruising at Mach 3.2 or more. It was visible on air traffic control radar for hundreds of miles, even when not using its transponder.[19] SR-71s were evidently detected by radar, as missiles were often fired at them.

In the end, the SR-71's greatest protection was its high top speed, which made it almost invulnerable to the attack technologies of the time; over the course of its service life, not one was shot down, despite over 4,000 attempts to do so. All the pilot had to do when a SAM was fired was to accelerate. The stealth and speed was very advanced for its time.

Chines

One of the Blackbird's interesting features was its chines, sharp edges leading aft on either side of the nose and along the sides of the fuselage.

The Blackbird was originally not going to have chines. At its "A-11" design stage, it looked similar to an enlarged F-104. Lockheed's aerodynamicists were concerned that these large surfaces would adversely affect the aircraft's aerodynamic performance. But the government agencies paying for the project wanted drastically reduced radar cross-section, and pushed Lockheed's aerodynamicists to try chines on a few wind-tunnel models near the end of the configuration design process.

The aerodynamicists discovered that the chines generated powerful vortices around themselves, generating much additional lift near the front of the aircraft, leading to surprising improvements in aerodynamic performance. The angle of incidence of the delta wings could then be reduced, allowing for greater stability and less high-speed drag, and more weight (fuel) could be carried, allowing for greater range. Landing speeds were also reduced, since the chines' vortices created turbulent flow over the wings at high angles of attack, making it harder for the wings to stall. (The Blackbird can, consequently, make high-alpha turns to the point where the Blackbird's unique engine air inlets stop ingesting enough air, which can cause the engines to flame out. Blackbird pilots were thus warned not to pull more than 3 g, so that angles of attack stay low enough for the engines to get enough air).

The chines act like the leading edge extensions that increase the agility of modern fighters such as the F-5, F-16, F/A-18, MiG-29 and Su-27. The addition of chines also allowed designers to drop the planned canard foreplanes. (Many early design models of what became the Blackbird featured canards).

When the Blackbird was being designed, no other airplane had featured chines, so Lockheed's engineers had to solve problems related to the differences in stability and balance caused by these unusual surfaces. Their solutions have since been extensively used. Chines remain an important design feature of many of the newest stealth UAVs, such as the Dark Star, Bird of Prey, X-45 and X-47, since they allow for tail-less stability as well as for stealth.

Fuel

An air-to-air overhead front view of an SR-71A strategic reconnaissance aircraft. Note the water vapor, condensed by the low-pressure vortices generated by the chines outboard of each engine inlet.

SR-71 development began using a coal slurry powerplant,[15] but Johnson determined that the coal particles damaged engine components. He then began researching a liquid hydrogen powerplant, but the tanks required to store cryogenic hydrogen did not suit the Blackbird's form factor.

The focus then became somewhat more conventional, though still specialized in many ways. The result was JP-7 jet fuel, which had a relatively high flash point (140 °F, 60 °C) to cope with the heat.

In fact, the fuel was used as a coolant and hydraulic fluid in the aircraft before being burned. The fuel also contained fluorocarbons to increase its lubricity, an oxidizing agent to enable it to burn in the engines, and even a cesium compound, A-50, which disguised the exhaust's radar signature.

JP-7 is very slippery and extremely difficult to light in any conventional way. The slipperiness was a disadvantage on the ground, because the aircraft leaked small amounts of fuel when not flying, but at least JP-7 was not a fire hazard. When the engines of the aircraft were started, puffs of triethylborane (TEB), which ignites on contact with air, were injected into the engines to produce temperatures high enough to ignite the JP-7 initially. The TEB produced a characteristic puff of greenish flame that could often be seen as the engines were ignited.[16] TEB was also used to ignite the afterburners. The aircraft had only 20 fluid ounce (600 ml) of TEB on board for each engine, enough for at least 16 injections (a counter advised the pilot of the number of TEB injections remaining), but this was more than enough for the requirements of any missions it was likely to carry out.

Life support

Crews flying the SR-71 at 80,000 ft (24,000 m) faced two main survival problems: 1) With a standard pressure demand oxygen mask, human lungs cannot absorb enough of 100% oxygen above 43,000 ft (13,000 m) to sustain consciousness and life, and 2) the instant heat rise pulse on the body when exposed to a Mach 3.2 air flow during ejection would be about 450 °F (230 °C). To solve these problems, the David Clark Company was hired to produce protective full pressure suits for all of the crew members of the A-12, YF-12, MD-21 and SR-71 aircraft. These suits were later adopted for use on the Space Shuttle during ascent.

In addition, at Mach 3.2 cruise the external heat rise due to the compression of air on the vehicle creating a surface heat well above 500 °F (260 °C) and would even heat up the inside of the windshield to 250 °F (120 °C) and cooling of the crew members was vital. This was achieved by cooling the air with an air conditioner. The air conditioner dumped the heat from the cockpit into the fuel prior to combustion via a heat exchanger.

After a high altitude bailout, an oxygen supply would keep the suit pressurized. The crew member would then free-fall to 15,000 ft (4,600 m) before the main parachute was opened, allowing the high heat rise to bleed off as the crew member slowed down and descended. To demonstrate this full pressure suit capability, crew members would wear one of these suits and undergo an altitude chamber explosive decompression to 78,000 ft (24,000 m) or higher while chamber heaters would rapidly turn on to 450 °F (230 °C) and then be turned down at the rate experienced during a real life free-fall.

The cabin could be pressurized to an altitude of 10,000 ft (3,000 m) or 26,000 ft (7,900 m) during flight.[28] So crews flying a low-subsonic flight (such as a ferry mission) would wear either their full pressure suit or standard USAF hard hat helmets, pressure demand oxygen masks and nomex flying suits.

Titanium structures and skin

Before the Blackbird, titanium could only be found in aircraft in high-temperature exhaust fairings and other small parts directly related to supporting, cooling, or shaping high-temperature areas. Building the Blackbird's structure using 85% titanium and 15% composite materials was a first in the aircraft industry. The advances made by Lockheed in fabricating this material have been used in subsequent high-speed aircraft, including most modern fighters.

Titanium was difficult to work with, expensive, and scarce. Initially, 80% of the titanium delivered to Lockheed was rejected due to metallurgical contamination. One example of the difficulties of working with titanium is that welds made at certain times of the year were more durable than welds made at other times. It was found that the manufacturing plant's water came from one reservoir in the summer and another in the winter; the slight differences in the impurities in the water from these sources led to differences in the durability of the welds, since water was used to cool the titanium welds.

Studies of the aircraft's titanium skin revealed that the metal was actually growing stronger over time, because of intense heating due to compression of the air, caused by the rapid flight of the vehicle (heat treatment).

Major portions of the upper and lower inboard wing skin of the SR-71 were corrugated, not smooth. The thermal expansion stresses of a smooth skin would have caused splitting or curling. By making the surface corrugated, the skin was allowed to expand vertically and horizontally without overstressing, which also increased longitudinal strength. Despite its success, aerodynamicists initially opposed the concept and accused the design engineers of trying to make a 1920s era Ford Trimotor — known for its corrugated aluminum skin — go Mach 3.

The red stripes on some SR-71s are to prevent maintenance workers from damaging the skin. The curved skin near the center of the fuselage is thin and delicate. There is no support underneath with exception of the structural ribs, which are spaced several feet apart.

Engines

Pratt & Whitney J58 engines beneath the SR-71 Blackbird on display at Imperial War Museum Duxford.

The Pratt & Whitney J58-P4 engines used in the Blackbird were the only military engines ever designed to operate continuously on afterburner, and became more efficient as speed increased.

Each J58 engine could produce 32,500 lbf (145 kN) of static thrust. Conventional jet engines cannot operate continuously on afterburner.

The J58 was unique in that it was a hybrid jet engine. It could operate as a regular turbojet at low speeds, but at high speeds it became a ramjet. The engine can be thought of as a turbojet engine inside a ramjet engine. At lower speeds, the turbojet provided most of the compression and most of the energy from fuel combustion. At higher speeds, the turbojet throttled back and just sat in the middle of the engine as air bypassed around it, having been compressed by the shock cones and only burning fuel in the afterburner.

In detail, air was initially compressed (and thus also heated) by the shock cones, which generated shock waves that slowed the air down to subsonic speeds relative to the engine. The air then passed through four compressor stages and was split by moveable vanes: some of the air entered the compressor fans ("core-flow" air), while the rest of the air went straight to the afterburner (via six bypass tubes). The air traveling through the turbojet was further compressed (and further heated), and then fuel was added to it in the combustion chamber: it then reached the maximum temperature anywhere in the Blackbird, just under the temperature where the turbine blades would start to soften.

After passing through the turbine (and thus being cooled somewhat), the core-flow air went through the afterburner and met with any bypass air.

At around Mach 3, the increased heating from the shock cone compression, plus the heating from the compressor fans, was already enough to get the core air to high temperatures, and little fuel could be added in the combustion chamber without the turbine blades melting. This meant the whole compressor-combustor-turbine set-up in the core of the engine provided less power, and the Blackbird flew predominantly on air bypassed straight to the afterburners, forming a large ramjet effect. No other aircraft does this. (This shows how the temperature tolerance of the turbine blades in a jet engine determine how much fuel can be burned, and thus to a great extent determine how much thrust a jet engine can provide.)[15] The maximum speed was limited by the specific maximum temperature for the compressor inlet of 800 °F (427 °C).

Originally, the Blackbird's engines started up with the assistance of an external "start cart", a cart containing two Buick Wildcat V8 engines positioned underneath the aircraft. The two engines powered a single, vertical driveshaft connecting to a single J58 engine. Once one engine was started, the cart was wheeled to the other side of the aircraft to start the other engine. The operation was deafening. Later big block Chevrolet engines were used. Eventually, a quieter, pneumatic start system was developed for use at Blackbird main operating bases, but the start carts remained in the inventory to support recovery team Blackbird starts at diversion landing sites not equipped to start J-58 engines.

Astro-Inertial Navigation System (ANS)

Blackbird precision navigation requirements for route accuracy, sensor pointing and target tracking preceded the development and fielding of the Global Positioning System (GPS). U-2 and A-12 Inertial

Navigation Systems existed, but US Air Force planners wanted a system that would limit inertial position error growth for longer missions envisioned for the R-12 / SR-71.

Nortronics, the electronics development organization of Northrop, had extensive astro-inertial experience, having provided an earlier generation system for the USAF Snark missile. With this background, Nortronics developed the Astro-Inertial Navigation System for the AGM-48 Skybolt missile, which was to be launched from B-52H bombers. When the Skybolt Program was cancelled in December 1962, the assets Nortronics developed for the Skybolt Program were ordered to be adapted for the Blackbird program. A Nortronics "Skunkworks" type organization in Hawthorne,

California completed the development of this system, sometimes referred to as the NAS-14 and/or the NAS-21.

The ANS primary alignment was done on the ground and was time consuming, but brought the inertial components to a high degree of accuracy for the start of a mission. A "blue light" source star tracker, which could detect and find stars during day or night, would then continuously track stars selected from the system's digital computer ephemeris as the changing aircraft position would bring them into view. Originally equipped with data on 56 selected stars, the system would correct inertial orientation errors with celestial observations. The resulting leveling accuracies obtained limited accelerometer errors and position growth.

Rapid ground alignments and air-start abilities were later developed and added to the ANS. Attitude and position inputs to on-board systems and flight controls included the Mission Data Recorder, Auto-Nav steering between loaded destination points, automatic pointing and control of cameras at control points and optical or SLR sighting of fix points (this mission data being tape loaded into the ANS prior to takeoff).

The ANS was located behind the RSO station and tracked stars through a round quartz window in the upper fuselage. Cooling in the Blackbird Mach 3.2+ cruising environment was a serious challenge, resolved by Lockheed and Nortronics engineers during the early test phases. The ANS was a reliable and accurate self-contained navigation system.

Note: The original B-1A Offensive Avionics Request For Proposal (RFP) required the installation and integration of an NAS-14 system, but cost-cutting changes later deleted it from the B-1. Some U-2Rs did receive the NAS-21 system, but newer Inertial and GPS systems replaced them.

Sensors and payloads

Original capabilities for the SR-71 included optical/infrared imagery systems, side-looking airborne radar (SLAR), electronic intelligence (ELINT) gathering systems, defensive systems (for countering missile and airborne fighter threats) and recorders for SLAR, ELINT and maintenance data.

Imagery systems used on the Blackbird were diverse. At the simple end of the spectrum, SR-71s were equipped with a Fairchild tracking camera of modest resolution and an HRB Singer infrared-tracking IR camera, both of which ran during the entire mission to document where the aircraft flew and answer any post-flight political charges of overflight.

While the A-12's principal sensor was a single large focal length optical camera located in the "Q-Bay", behind the pilot, that location was taken by the cockpit for the observer in the SR-71, forcing the use of different camera systems, which could be located in the wing chines or in the interchangeable nose of the aircraft. Wide area imaging was provided by two of Itek's Operational Objective Cameras (OOC) that provided stereo imagery left and right of the flight track, or an Itek Optical Bar Camera (OBC) that replaced the OOCs and was carried in the nose in place of the SLR, which gave continuous horizon-to horizon coverage. A closer view of the target area was given by the HYCON

Technical Objective Camera (TEOC), that could look straight down or up to 45 degrees left or right of centerline. SR-71s were equipped with two of them, each with a six-inch (152 mm) resolution and the ability to show such details as the painted lines in parking lots from an altitude of 83,000 feet (25,000 m).[citation needed] During the early years of service, the resolution produced by the smaller TEOCs was less than that of the larger camera carried by the A-12, although improvements in the camera and the film used later greatly improved the cameras performance. In the later years of the SR-71 operation, usage of the infrared camera was discontinued.

Side-looking radar, built by Goodyear Aerospace in Arizona, was carried in the removable nose section (which could be loaded with the SLR antenna in the maintenance shop before installation on the Blackbird). It was eventually replaced by Loral's Advanced Synthetic Aperture Radar System (ASARS-1) and built and supported by Goodyear. Both the first SLR and ASARS-1 were ground mapping imaging systems and could collect data in fixed swaths left or right of centerline or from a spot location where higher resolution was desired.[35] As an example, in passing abeam of an open door aircraft hangar, ASARS-1 could provide meaningful data on the hangar's contents.

ELINT gathering systems, called the Electro Magnetic Reconnaissance System (EMR) built by AIL could be carried in both the left and right chine bays to provide a wide view of the electronic signal fields the Blackbird was flying through. Computer-loaded instructions looked for items of special intelligence interest.

Defensive systems built by several leading electronic countermeasures (ECM) companies included (and evolved over the years of the Blackbird's operational life) Systems A, A2, A2C, B, C, C2, E, G, H and M. Several of these different frequency/purpose payloads would be loaded for a particular mission to match the threat environment expected for that mission. They, their warning and active electronic capabilities, and the Blackbird's ability to accelerate and climb when under attack, resulted in the SR-71's long and proven survival track-record.

Recording systems captured SLR phase shift history data (for ground correlation after landing), ELINT-gathered data, and Maintenance Data Recorder (MDR) information for post-flight ground analysis of the aircraft and its systems' overall health. From an altitude of 80,000 feet (24,000 m), it could survey 100,000 square miles (260,000 km2) per hour of the Earth's surface.

In the later years of its operational life, a data-link system was added that would allow ASARS-1 and ELINT data from about 2,000 nmi (3,700 km) of track coverage to be downlinked if the SR-71 was within "contact" with a mutually-equipped ground station.

Operational history

The first flight of an SR-71 took place on 22 December 1964, at Air Force Plant 42 in Palmdale, California The first SR-71 to enter service was delivered to the 4200th (later, 9th) Strategic Reconnaissance Wing at Beale Air Force Base, California, in January 1966. The United States Air Force Strategic Air Command had SR-71 Blackbirds in service from 1966 through 1991.

SR-71s first arrived at the 9th SRW's Operating Location (OL-8) at Kadena Airbase, Okinawa on 8 March 1968. These deployments were code named "Glowing Heat", while the program as a whole was code named "Senior Crown". Reconnaissance missions over North Vietnam were code named "Giant Scale".

On 21 March 1968, Major (later General) Jerome F. O'Malley and Major Edward D. Payne flew the first operational SR-71 sortie in SR-71 serial number 61-7976 from Kadena AB, Okinawa. During its career, this aircraft (976) accumulated 2,981 flying hours and flew 942 total sorties (more than any other SR-71), including 257 operational missions, from Beale AFB; Palmdale, California; Kadena Air Base, Okinawa, Japan;

and RAF Mildenhall, England. The aircraft was flown to the National Museum of the United States Air Force near Dayton, Ohio in March 1990.

From the beginning of the Blackbird's reconnaissance missions over enemy territory (North Vietnam, Laos, etc.) in 1968, the SR-71s averaged approximately one sortie a week for nearly two years. By 1970, the SR-71s were averaging two sorties per week, and by 1972, they were flying nearly one sortie every day.

While deployed in Okinawa, the SR-71s and their aircrew members gained the nickname Habu (as did the A-12s preceding them) after a pit viper indigenous to Japan, which the Okinawans thought the plane resembled.

Operational highlights for the entire Blackbird family (YF-12, A-12, and SR-71) as of about 1990 included:

. 3,551 Mission Sorties Flown

. 17,300 Total Sorties Flown

. 11,008 Mission Flight Hours

. 53,490 Total Flight Hours

. 2,752 hours Mach 3 Time (Missions)

. 11,675 hours Mach 3 Time (Total)

Only one crew member, Jim Zwayer, a Lockheed flight-test reconnaissance and navigation systems specialist, was killed in a flight accident. The rest of the crew members ejected safely or evacuated their aircraft on the ground.

The highly specialized tooling used in manufacturing the SR-71 was ordered to be destroyed in 1968 by then-Secretary of Defense Robert McNamara, per contractual obligations at the end of production. Destroying the tooling killed any chance of there being an F-12B, but also limited the SR-71 force to the 32 completed, the final SR-71 order having to be cancelled when the tooling was destroyed.

First retirement

In the 1970s, the SR-71 was placed under closer congressional scrutiny and, with budget concerns, the program was soon under attack. Both Congress and the USAF sought to focus on newer projects ike the B-1 Lancer and upgrades to the B-52 Stratofortress, whose replacement was being developed. While the development and construction of reconnaissance satellites was costly, their upkeep was less than that of the nine SR-71s then in service.

The SR-71 had never gathered significant supporters within the Air Force, making it an easy target for cost-conscious politicians. Also, parts were no longer being manufactured for the aircraft, so other airframes had to be cannibalized to keep the fleet airworthy. The aircraft's lack of a datalink (unlike the Lockheed U-2) meant that imagery and radar data could not be used in real time, but had to wait until the aircraft returned to base. The Air Force saw the SR-71 as a bargaining chip which could be sacrificed to ensure the survival of other priorities. A general misunderstanding of the nature of aerial reconnaissance and a lack of knowledge about the SR-71 in particular (due to its secretive development and usage) was used by detractors to discredit the aircraft, with the assurance given that a replacement was under development. In 1988, Congress was convinced to allocate $160,000 to keep six SR-71s (along with a trainer model) in flyable storage that would allow the fleet to become airborne within 60 days. The USAF refused to spend the money. While the SR-71 survived attempts to be retired in 1988, partly due to the unmatched ability to provide high quality coverage of the Kola Peninsula for the US Navy, the decision to retire the SR-71 from active duty came in 1989, with the SR-71 flying its last missions in October that year.

Funds were redirected to the financially troubled B-1 Lancer and B-2 Spirit programs. Four months after the plane's retirement, General Norman Schwarzkopf, Jr., was told that the expedited reconnaissance which the SR-71 could have provided was unavailable during Operation Desert Storm. However, it was noted by SR-71 supporters that the SR-71B trainer was just coming out of overhaul and that one SR-71 could have been made available in a few weeks, and a second one within two months. Since the plane was recently retired, the support infrastructure was in place and qualified crews available. The decision was made by Washington not to bring the aircraft back.

Reactivation

Due to increasing unease about political conditions in the Middle East and North Korea, the U.S. Congress re-examined the SR-71 beginning in 1993. At a hearing of the Senate Committee on Armed Services, Senator J. James Exon (noting Senator John Glenn's disapproval of reactivating the SR-71) asked Admiral Richard C. Macke:

“ .If we have the satellite intelligence that you collectively would like us to have, would that type of system eliminate the need for an SR-71… Or even if we had this blanket up there that you would like in satellites, do we still need an SR-71?.

Macke replied, .From the operator's perspective, what I need is something that will not give me just a spot in time but will give me a track of what is happening. When we are trying to find out if the Serbs are taking arms, moving tanks or artillery into Bosnia, we can get a picture of them stacked up on the Serbian side of the bridge. We do not know whether they then went on to move across that bridge. We need the [data] that a tactical, an SR-71, a U-2, or an unmanned vehicle of some sort, will give us, in addition to, not in replacement of, the ability of the satellites to go around and check not only that spot but a lot of other spots around the world for us. It is the integration of strategic and tactical."

Rear Admiral Thomas F. Hall addressed the question of why the SR-71 was retired, saying it was under

" the belief that, given the time delay associated with mounting a mission, conducting a reconnaissance, retrieving the data, processing it, and getting it out to a field commander, that you had a problem in timeliness that was not going to meet the tactical requirements on the modern battlefield. And the determination was that if one could take advantage of technology and develop a system that could get that data back real time… that would be able to meet the unique requirements of the tactical commander." Hall stated that "the Advanced Airborne Reconnaissance System, whichwas going to be an unmanned UAV. would meet the requirements but was not affordable at the time. He said that they were .looking at alternative means of doing [the job of the SR-71]."

Macke told the committee that they were .flying U-2s, RC-135s, [and] other strategic and tactical assets. to collect information in some areas.

Senator Robert Byrd and other Senators complained that the .better than. successor to the SR-71 had yet to be developed at the cost of the "good enough" serviceable aircraft. They maintained that, in a time of constrained military budgets, designing, building, and testing an aircraft with the samecapabilities as the SR-71 would be impossible.

Congress' disappointment with the lack of a suitable replacement for the Blackbird was cited concerning whether to continue funding imaging sensors on the U-2. Congressional conferees stated the "experience with the SR-71 serves as a reminder of the pitfalls of failing to keep existing systems up-to-date and capable in the hope of acquiring other capabilities."

It was agreed to add $100 million to the budget to return three SR-71s to service, but it was emphasized that this "would not prejudice support for long-endurance UAVs [such as the Global Hawk]." The funding was later cut to $72.5 million. The Skunk Works was able to return the aircraft to service under budget, coming in at $72 million.

Colonel Jay Murphy (USAF Retired) was made the Program Manager for Lockheed's reactivation plans. Retired Air Force Colonels Don Emmons and Barry MacKean were put under government contract to remake the plane's logistic and support structure. Still-active Air Force pilots and Reconnaissance Systems Officers (RSOs) who had worked with the aircraft were asked to volunteer to fly the reactivated planes. The aircraft was under the command and control of the 9th Reconnaissance Wing at Beale Air Force Base and flew out of a renovated hangar at Edwards Air Force Base. Modifications were made to provide a data-link with "near real-time" transmission of the Advanced Synthetic Aperture Radar's imagery to sites on the ground.

Second retirement

The reactivation met much resistance: the Air Force had not budgeted for the aircraft, and UAV developers worried that their programs would suffer if money was shifted to support the SR-71s. Also, with the allocation requiring yearly reaffirmation by Congress, long-term planning for the SR-71 was difficult. In 1996, the Air Force claimed that specific funding had not been authorized, and moved to ground the program. Congress reauthorized the funds, but, in October 1997, President Bill Clinton sed the line-item veto to cancel the $39 million allocated for the SR-71. In June 1998, the Supreme Court of the United States ruled that the line-item veto was unconstitutional. All this left the SR-71's status uncertain until September 1998, when the Air Force called for the funds to be redistributed.

The plane was permanently retired in 1998. The Air Force quickly disposed of their SR-71s, leaving NASA with the two last flyable Blackbirds until 1999.[48] All other Blackbirds have been moved to museums except for the two SR-71s and a few D-21 drones retained by the NASA Dryden Research Center.

SR-71 timeline

Important dates pulled from many sources.

. 24 December 1957: First J58 engine run.

. 1 May 1960: Francis Gary Powers is shot down in a Lockheed U-2 over the Soviet Union.

. 13 June 1962: SR-71 mock-up reviewed by Air Force.

. 30 July 1962: J58 completes pre-flight testing.

. 28 December 1962: Lockheed signs contract to build six SR-71 aircraft.

. 25 July 1964: President Johnson makes public announcement of SR-71.

. 29 October 1964: SR-71 prototype (#61-7950) delivered to Palmdale.

. 7 December 1964: Beale AFB, CA announced as base for SR-71.

. 22 December 1964: First flight of the SR-71 with Lockheed test pilot Bob Gilliland at AF Plant #42.

. 21 July 1967: Jim Watkins and Dave Dempster fly first international sortie in SR-71A #61-7972 when the Astro-Inertial Navigation System (ANS) fails on a training mission and they accidentally fly into Mexican airspace.

. 3 November 1967: A-12 and SR-71 conduct a reconnaissance fly-off. Results were questionable.

. 5 February 1968: Lockheed ordered to destroy A-12, YF-12, and SR-71 tooling.

. 8 March 1968: First SR-71A (#61-7978) arrives at Kadena AB to replace A-12s.

. 21 March 1968: First SR-71 (#61-7976) operational mission flown from Kadena AB over Vietnam.

. 29 May 1968: CMSgt Bill Gornik begins the tie-cutting tradition of Habu crews neck-ties.

. 18 December 1969: 1969 United States Air Force SR-71 crash

. 3 December 1975: First flight of SR-71A #61-7959 in "Big Tail" configuration.

. 20 April 1976: TDY operations started at RAF Mildenhall in SR-71A #17972.

. 27 July 1976 - 28 July 1976: SR-71A sets speed and altitude records (Altitude in Horizontal Flight: 85,068.997 ft (25,929.030 m) and Speed Over a Straight Course: 2,193.167 mph).

. August 1980: Honeywell starts conversion of AFICS to DAFICS.

. 15 January 1982: SR-71B #61-7956 flies its 1,000th sortie.

. 21 April 1989: #974 was lost due to an engine explosion after taking off from Kadena AB. This was the last Blackbird to be lost, it was the first SR-71 accident in 18 years, and it is also the longest accident-free streak of any USAF aircraft.

. 22 November 1989: Air Force SR-71 program officially terminated.

. 21 January 1990: Last SR-71 (#61-7962) left Kadena AB.

. 26 January 1990: SR-71 is decommissioned at Beale AFB, CA.

. 6 March 1990: Last SR-71 flight under SENIOR CROWN program, setting four speed records enroute to Smithsonian Institution.

. 25 July 1991: SR-71B #61-7956/NASA #831 officially delivered to NASA Dryden.

. October 1991: Marta Bohn-Meyer becomes first female SR-71 crew-member.

. 28 September 1994: Congress votes to allocate $100 million for reactivation of three SR-71s.

.26 April 1995: First reactivated SR-71A (#61-7971) makes its first flight after restoration by Lockheed.

.28 June 1995: First reactivated SR-71 returns to Air Force as Detachment 2.

.28 August 1995: Second reactivated SR-71A (#61-7967) makes first flight after restoration.

. 2 August 1997: A NASA SR-71 made multiple flybys at the Oshkosh Airventure air show. It was then supposed to perform a sonic boom at 53,000 feet (16,000 m) after a midair refueling, but a fuel flow problem caused it to divert to Milwaukee. Two weeks later, the pilot's flight path brought him over Oshkosh again, and there was, in fact, a sonic boom.

. 19 October 1997: The last flight of SR-71B #61-7956 at Edwards AFB Open House.

. 9 October 1999: The last flight of the SR-71 (#61-7980/NASA 844).

. September 2002: Final resting places of #956, #971, and #980 are made known.

. 15 December 2003: SR-71 #972 goes on display at the Steven F. Udvar-Hazy Center in Chantilly, Virginia.

Records

The SR-71 was the world's fastest and highest-flying operational manned aircraft throughout its career. On 28 July 1976, an SR-71 broke the world record for its class: an absolute speed record of 1,905.81 knots (2,193.17 mph; 3,529.56 km/h), and an "absolute altitude record" of 85,069 feet (25,929 m). Several aircraft exceeded this altitude in zoom climbs but not in sustained flight.

When the SR-71 was retired in 1990, one example was flown from its birthplace at United States Air Force Plant 42 in Palmdale, California, to go on exhibit at what is now the Smithsonian Institution's Steven F. Udvar-Hazy Center (an annex of the National Air & Space Museum) in Chantilly, Virginia.

On 6 March 1990, Lt. Col. Ed Yielding and Lt. Col. J. T. Vida piloted the Blackbird, setting a coast-to-coast aircraft speed record: 67 minutes 54 seconds, at an average speed 2,125 miles per hour (3,420 km/h). Three additional records were set within segments of the flight, including an average speed of 2,190 miles per hour (3,520 km/h) measured between the radar gates set up in St. Louis and Cincinnati. These four speed records were accepted by the National Aeronautic Association (NAA), the recognized body for aviation records in the United States.. An enthusiast site devoted to the Blackbird lists a record time of 64 minutes 20 seconds between Los Angeles and Washington DC for that 6 March 1990 flight.

The SR-71 also holds the "Speed Over a Recognized Course" record for flying from New York to London in 1 hour 54 minutes and 56.4 seconds, set on 1 September 1974 while flown by U.S. Air Force Pilot Maj. James V. Sullivan and Maj. Noel F. Widdifield, reconnaissance system officer. This equates to an average velocity of about Mach 2.68, including deceleration for in-flight refueling. Peak speeds during this flight were probably closer to the declassified top speed of Mach 3.2+. (For comparison, the best commercial Concorde flight time was 2 hours 52 minutes, and the Boeing 747 averages 6 hours 15 minutes.) It also holds the record of highest flown aircraft, reaching 85,000 ft.

Variants

The SR-71A was the main production variant. The SR-71B was a trainer variant. Production of the SR-71 totaled 32 aircraft with 29 SR-71As, 2 SR-71Bs, and 1 SR-71C.

The SR-71C was a hybrid aircraft composed of the rear fuselage of the first YF-12A (S/N 60-6934) and the forward fuselage from a SR-71 static test unit. This Blackbird was seemingly not quite straight and had a yaw at supersonic speeds. It was nicknamed "The Bastard". The YF-12 had been wrecked in a 1966 landing accident.

Flight simulator

The Link Simulator Company's SR-71 Flight Simulator was developed during 1963 – 1965 under a deep "black" security blanket because it and the team Link assigned to it were given access to CIA OXCART and USAF R-12 / SR-71 clearances, the complete list of names of classified vendors supplying parts and software that had to be simulated, the total aircraft performance envelope data and a government-produced satellite photo montage of almost the entire continental United States to provide optical imagery for the RSO's portion of the Flight Simulator. This later capability was mounted on a separate, large, rectangular glass plate (approximately 6 feet (1.8 m) by 12 feet (3.7 m) in size) over which moved an optical sighting head that traveled at the scaled speed and direction of the Blackbird during its simulated flight. Realistic and accurate images were then displayed in the Optical View Sight and SLR RCD (Radar Correlator Display) in the RSO cockpit. Imagery was not provided to the pilot's simulator, which like the RSO simulator, had translucent window panels with varying degrees of lighting to change a simulated flight from daylight to night flying conditions. Instructor positions were behind both the pilot's and the RSO's cockpits, with monitoring, malfunction and emergency problem controls provided. The simulator halves could be flown as separate cockpits with different training agendas or in a team mode, where intercom, instrument readings and air vehicle/sub-systems performance were integrated. Although most simulator flights were in a flight suit "shirt sleeve" environment, selected flights during a crew's checkout training were made with the crew wearing the complete David Clark Company's Full Pressure Suit.

In 1965, when the first Beale AFB Instructor Pilot/RSO crew (in civilian attire) visited the Flight Simulator during USAF checkout and acceptance trials at Link's upstate New York facilities, they were surprised to park in front of a busy, active grocery store and then be escorted to a side door that led to a hidden, rear portion of the building that was Link's classified "Skunkworks" type facility for the Blackbird program. Secrecy was so complete that no one in the township was aware of what was happening behind the busy checkout stands selling groceries.

In 1965, the Flight Simulator was transferred to Beale AFB, California and the 9th Strategic Reconnaissance Wing's SAGE building, which provided vault level security for it plus the Wing Headquarters, Flight Mission Planning, and Intelligence Analysis / Exploitation of Blackbird mission products.

Besides SR-71 flight crew training and currency usage, the Flight Simulator was used several times by Lockheed and CIA operatives to analyze Groom Lake A-12 problems and accidents, with similar assistance provided for SR-71 flights at Edwards AFB. Another unique feature was that an actual flight mission tape for the SR-71 ANS could be loaded into the Flight Simulator's digital computers, which had been designed and programmed by Link engineers to emulate the Nortronics ANS. During Category II testing at Edwards AFB, some types of ANS navigation errors could be duplicated in the Flight Simulator at Beale AFB, with Link engineers then often assisting in software fixes to the main ANS flight software programs.

At the conclusion of SR-71 flying at Beale AFB, the Flight Simulator (minus the RSO optical imagery system) was transferred to the NASA Dryden facility at Edwards AFB in support of NASA SR-71 flight operations. Upon completion of all USAF and NASA SR-71 operations at Edwards, the Flight Simulator was moved in July, 2006 to the Frontiers of Flight Museum on Love Field Airport in Dallas, Texas and, with support from the Museum and Link (now, L-3 Communications, Link Simulation and Training), it is intended for viewing by Museum visitors.

Myth and lore

The plane developed a small cult following, given its design, specifications and the secrecy surrounding it. Specifically, these groups cite that the aircraft's maximum speed is limited by the specific maximum temperature for the compressor inlet of 800 °F (427 °C). Recent studies of inlets of this type have shown that current technology could allow for inlet speeds with a lower limit of Mach 6.

It is known that the J58 engines were most efficient at around Mach 3.2, and this was the Blackbird's typical cruising speed. The SR-71's Pratt & Whitney J58 engines never exceeded test bench values above Mach 3.6 in unclassified tests.

The SR-71 was the first operational aircraft designed around a stealthy shape and materials. The most visible marks of its low radar cross section (RCS) are its inwardly-canted vertical stabilizers and the fuselage chines. Comparably, a plane of the SR-71's size should generate a radar image the size of a barn, but its actual return is more like that of a single door. Though with a much smaller RCS than expected for a plane of its size, it was still easily detected, because the exhaust stream would return its own radar signature (even though a special cesium compound was added to the fuel to reduce this signature). Furthermore, this is no comparison to the later F-117, whose RCS is on the order of a small ball bearing.

Swedish JA-37 Viggen fighter pilots, using the predictable patterns of SR-71 routine flights over the Baltic Sea, managed to lock their radar on the SR-71. On at least one occasion the aftermath resulted in one of the Swedish pilots receiving an acknowledgment for his achievements. The most common site for the lock-on to occur was the thin stretch of international airspace between Öland and Gotland that the SR-71 used on the return flight.

Succession

Much speculation exists regarding a replacement for the SR-71, most notably an aircraft identified as the Lockheed Aurora. This is due to limitations of spy satellites, which are governed by the laws of Orthographically projected diagram of the SR-71A Blackbird. Due to orbital mechanics. It may take 24 hours before a satellite is in proper orbit to photograph a particular target, far longer than a reconnaissance plane. Spy planes can provide the most current intelligence information and collect it when lighting conditions are optimum. The fly-over orbit of spy satellites may also be predicted and can allow the enemy to hide assets when they know the satellite is above, a drawback spy planes lack. These factors have led many to doubt that the US has abandoned the concept of spy planes to complement reconnaissance satellites.

Specifications (SR-71A)

Data from SR-71.org

General characteristics

. Crew: 2

. Payload: 3,500 lb (1,600 kg) of sensors

. Length: 107 ft 5 in (32.74 m)

. Wingspan: 55 ft 7 in (16.94 m)

. Height: 18 ft 6 in (5.64 m)

. Wing area: 1,800 ft2 (170 m2)

. Empty weight: 67,500 lb (30,600 kg)

. Loaded weight: 170,000 lb (77,000 kg)

. Max takeoff weight: 172,000 lb (78,000 kg)

. Powerplant: 2× Pratt & Whitney J58-1 continuous-bleed afterburning turbojets, 32,500 lbf (145 kN) each

. Wheel track: 16 ft 8 in (5.08 m)

. Wheel base: 37 ft 10 in (11.53 m)

. Aspect ratio: 1.7

Performance

. Maximum speed: Mach 3.2+ (2,200+ mph, 3,530+ km/h, 1,900+ knots) at 80,000 ft (24,000 m)

. Range: 2,900 nmi (5,400 km)

. Ferry range: 3,200 nmi (5,925 km)

. Service ceiling: 85,000 ft (25,900 m)

. Rate of climb: 11,810 ft/min (60 m/s)

. Wing loading: 94 lb/ft² (460 kg/m²)

. Thrust/weight: 0.382