Lockheed SR-71

An SR-71 in flight

The **Lockheed SR-71 Type A**, unofficially known as the **Blackbird**, is a long-range, advanced, strategic reconnaissance aircraft developed from the Lockheed YF-12A and A-12 aircraft by Lockheed's Skunk Works (also responsible for the U-2 and many other advanced aircraft). The legendary "Kelly" Johnson, in particular, was the man behind many of the design's advanced concepts. The SR-71 was one of the first aircraft to be shaped to have an extremely low radar signature. The aircraft flew so fast and so high that if the pilot detected a surface-to-air missile launch, the standard evasive action was simply to accelerate. No SR-71 has ever been shot down.

History

Although the predecessor A-12 first flew in 1962, the first flight of an SR-71 took place on December 22, 1964, and 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 retired its fleet of SR-71s on January 26, 1990, because of a decreasing defense budget and high costs of operation. The USAF returned the SR-71 to the active Air Force inventory in 1995 and began flying operational missions in January 1997. The planes were permanently retired in 1998.

The SR-71 remained the world's fastest and highest-flying operational aircraft throughout its career. From an altitude of 80,000 ft (24 km) it could survey 100,000 miles²/h (72 km²/s) of the Earth's surface. On July 28, 1976, an SR-71 set two world records for its class: an absolute speed record of 2,193.167 mph (3,529.56 km/h) and an US absolute altitude record of 85,068.997 feet (25,929 m). Only the Soviet MIG-25 high-altitude interceptor broke the record, reaching an altitude 37,650 m on August 31, 1977 (MIG-25). When the SR-71 was retired in 1990, one was flown from its birthplace at United States Air Force Plant 42 in Palmdale to go on exhibit at what is now the Smithsonian Institute's Steven F. Udvar-Hazy Center (an annex of the National Air & Space Museum) in Chantilly, Virginia, setting a coast-to-coast speed record at an average 2,124 mph (3,418 km/h). The entire trip took 64 minutes.[1] The SR-71 also holds the record for flying from New York to London: 1 hour 54 minutes and 56.4 seconds, set on September 1, 1974. (For comparison, commercial Concorde flights took around 3 hours 20 minutes, and the Boeing 747 averages 7 hours.)

On March 21, 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 64-17976. 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, California; Palmdale, California; Kadena Air Base, Okinawa, Japan; and RAF Mildenhall, England. The aircraft was flown to the United States Air Force Museum near Dayton, Ohio in March 1990. In Okinawa, the A-12s (and later the SR-71s) gained their nickname Habu after a southeast Asian pit viper which the locals thought the plane resembled.

Thirty-two planes were built. Of these, 12 were lost in flight accidents. Only one crew member, RSO Jim Zwayer, was ever killed. The rest of the crews ejected safely.

The A-12 Oxcart, designed for the CIA by Kelly Johnson at the Lockheed Skunkworks, was a predecessor of the SR-71. Lockheed used the name "Archangel" for this design, but many documents use Johnson's preferred name for the plane, "the Article". As the design evolved, the internal Lockheed designation went from A-1 to A-11 as configuration changes occurred. The A-11 model was the first to fly as a test vehicle and was equipped with less powerful J-75s because development of the Pratt & Whitney J-58s intended for the Oxcart was delayed. When the J-58s finally arrived at the "Ranch" (Groom Lake's Area 51) and were installed as the 12th configuration change, the Article was renumbered the A-12, which it retained through production and operational usage. Eighteen were built, of which three were converted into YF-12As, prototypes of the planned F-12 interceptor version.

The Air Force reconnaissance version was originally called the R-12 (see the opening fly page in Paul Crickmoore's book *SR-71, Secret Missions Revealed*, which contains a copy of the original R-12 labeled plan view drawing of the vehicle). However, during the 1964 presidential campaign, Senator Barry Goldwater continuously criticized President Lyndon B. Johnson and his administration for falling behind the Soviet Union in the research and development of new weapon systems. Johnson decided to counter this criticism with the public release of the highly classified A-12 program and later the existence of the reconnaissance version.

The USAF had planned to redesignate the R-12 aircraft as the RS-71 (Reconnaissance-Strike) as the successor to the RS-70 Valkyrie, which had two test Valkyrie's flying at Edwards AFB, California. However, then USAF Chief of Staff Curtis LeMay preferred the SR designation and wanted the RS-70 to be named SR-70. Before the Blackbird was to be announced by Lyndon B. Johnson on February 29, 1964, LeMay lobbied to modify Johnson's speech to also 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 plane's designation. [2] [3]

This public disclosure of the program and its designation came as a shock to everyone at Skunkworks and Air Force personnel involved in the program; at this time all of the printed Maintenance Manuals, Flight Crew Handbooks (the source of Paul Crickmoore's page), training vufoils, slides and materials were still labeled "R-12" (The 18 June, 1965 Certificate of Completion issued by the Skunkworks to the first Air Force Flight Crews and their Wing Commander are labeled: "R-12 Flight Crew Systems Indoctrination, Course VIII" and signed by Jim Kaiser, Training Supervisor and Clinton P. Street, Manager, Flight Crew Training Department). Following LBJ's speech, the designation change was taken as an order from the Commander-In-Chief, and immediate republishing began of new materials retitled "SR-71" with 29,000 blueprints altered.

Variants

D-21B Drone mounted on MD-21 Blackbird

One notable variant of the basic A-12 design was the M-21. This was a A-12 platform modified by replacing the single seat aircraft's Q bay, which carried its main camera to a second cockpit for a launch control officer. The M-21 was used to carry and launch the D-21 drone, an unpiloted, faster and higher flying reconnaissance device.

Confusingly, this variant was known as the M-21 when the drone was absent, and the MD-21 when it was attached to the plane. The D-21 drone was completely autonomous, having been launched it would overfly the target, travel to a rendezvous point and eject its data package. The package would be recovered in midair by a C-130 Hercules and the drone would self destruct. The program to develop this system was canceled in 1966 after a drone crashed into the mother ship shortly after being launched, destroying the M-21 and killing the Launch Control Officer.

The only surviving M-21 is on display, along with a D-21B Drone, at the Museum of Flight in Seattle, Washington.

Details

The flight instrumentation of SR-71 Blackbird

The airframe was made of titanium obtained from the USSR during the height of the Cold War. Lockheed used all possible guises to prevent the Soviet government from knowing what the titanium was to be used for. In order to keep the costs under control, they 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 (the fuel was used as a heat sink for avionics cooling) and to act as camouflage against the sky.

The plane was designed to have a very small 'radar cross-section' — the SR-71 was an early stealth design. However, the radar signature aspects of the SR-71 design did not take into account the extremely hot engine exhaust, and it turns out that this exhaust can reflect radar. Ironically, the SR-71 is one of the largest targets on the FAA (Federal Aviation Administration) long range radars, which are able to track the plane at several hundred miles.

A critical design feature to allow achieving mach 3.0+ cruising speeds, yet provide subsonic air flow into the turbojet engines were the Air Inlets. At the front of each inlet was a sharp, pointed moveable 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 jack screw powered) travel to the rear up to a maximum of 26 inches. The original Air Inlet Computer was an analog design and based on pitot-static, pitch, roll, yaw, angle-of-attack, etc. inputs would determine how much movement aft (or fore) was required. By doing so, the spike tip would withdraw the shockwave riding on it into the inlet body where reflections of the shockwave from the inlet cowl to the spike and back to the cowl, etc. would cause a loss of energy and slow it down until a mach 1.0 shockwave was formed; the backside of which is subsonic air for ingestion into the engine compressor. This capture of the shockwave within the inlet was called "Starting the Inlet". Tremendous pressures would be built up inside the inlet and in front of the compressor face. Bleed holes and bypass doors were designed into the inlet and engine nacelles to handle some of this pressure and allow the Inlet to remain "Started". So significant was this inlet pressure build-up (pushing against the inlet structure) that at mach 3.2 cruise, it was estimated that 58% of the available thrust was being provided by the inlet, 17% by the compressor and the remaining 25% by the afterburner. 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).

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 incorrectly positioned) the shockwave would suddenly blow out the front of the inlet, called an "Inlet Unstart". Immediately, the air flow through the engine compressor would cease, thrust dropped and exhaust gas temperatures would begin to rise. Due to the tremendous thrust of the remaining engine pushing the aircraft asymmetrically along with the sudden deceleration caused by losing 50% of available power, an unstart would cause the aircraft to violently yaw to one side. SAS, autopilot and manual control inputs would fight the yawing, but often the off angle extreme 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. Pilots and RSOs occasionally experienced their Pressure Suit Helmets banging on their 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 crew would return to its acceleration and climb to planned cruise altitude.

Eventually, a Digital Air Inlet Computer replaced the original analog one. Lockheed engineers developed control software for the engine inlets that would recapture the lost shockwave and relight the engine before the pilot was even aware an unstart had occurred. The SR-71 machinists were responsible for the hundreds of precision adjustments of the forward air by-pass doors within the inlets. This helped control the shock wave, prevent unstarts and increase performance.

Due to the great temperature changes in flight, the fuselage panels did not fit perfectly on the ground and were essentially loose. Proper alignment was only achieved when the airframe warmed up, due to the 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 extreme temperatures, the aircraft would leak its 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 air-to-air refueled before departing on its mission. Cooling was carried out by cycling fuel behind the titanium surfaces at the front of the wings (chines). Nonetheless, once the airplane landed no one could approach it for some time as its canopy was still hotter than 300 degrees Celsius. Asbestos (non-fibrous) was also used, such as in non-ceramic automotive brakes, due to its high heat tolerance.

The chines themselves are an interesting and unique feature. The first studies in radar stealth seemed to indicate that a shape with flattened, tapering sides would reflect most radar away from the place where the radar beams originated. The Blackbird was originally not going to have chines - it would look not too different from an enlarged F-104 - but the radar engineers convinced the aerodynamicists to try adding them to a few wind-tunnel models during the design process. It was discovered that the chines generated powerful vortices around themselves, generating much additional lift near the front of the aircraft. 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 these powerful 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-G turns to the point where the engine air inlets stop working properly and the engines flame out). The chines act like the leading edge extensions which are used to increase the agility of many modern fighters such as the F-5, F-20, F-16, F/A-18, MiG-29 and Sukhoi-27. Once these advantages were observed during wind-tunnel tests of Blackbird models, the use of canard foreplanes was no longer needed. (Many early design models of what became the Blackbird featured canards.) Chines are still an important part of the design of many of the newest stealth UAVs, such as the DarkStar, Bird of Prey, X-45, and X-47, since they allow for tail-less stability as well as for stealth.

The JP-7 jet fuel is interesting in its own right: originally developed for the A-12 Oxcart plane in the late 1950s, it has an extremely high flash point to cope with the heat, to the extent that a match dropped in a bucket of JP-7 does not ignite it. The fuel also contains fluorocarbons to increase its lubricity, an oxidising agent to enable it to burn in the engines, and even a cesium compound, A-50, which disguises the exhaust's radar signature. As a result, JP-7 was claimed to be more expensive than malt Scotch whisky, which contributed to the $24-27,000/hr cost of operating the SR-71. For comparison, a U-2 costs only 1/3 as much. On the other hand, a U-2 travels at only 1/4 the speed and can not carry as much reconnaissance equipment on a single flight.

Studies of the aircraft's titanium skin revealed the metal was actually growing stronger over time due to the intense heating caused by aerodynamic friction, a process similar to annealing.

Major portions of the upper and lower inboard wing skin of the SR-71 are actually corrugated, not smooth. The thermal expansion stresses of a smooth skin would have resulted in the aircraft skin splitting or curling. By making the surface corrugated, the skin is allowed to expand vertically as well as horizontally without overstressing, which also increases longitudinal strength. Despite the fact that it worked, aerodynamicists were aghast at 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 J-58 engines used in the Blackbird are the only military engines ever designed to operate continuously on afterburner, and actually become more efficient as the aircraft goes faster. Each J-58 engine could produce 32,500 lbf (145 kN) of static thrust. Conventional jet engines cannot operate continuously on afterburner and lose efficiency as they go faster.

The J-58 is also unique in that it is a hybrid jet engine: it is effectively a turbojet engine that sits inside a ramjet engine. Air is initially compressed (and thus also heated) by the shock cones, and immediately afterwards it is split: some of the air enters the compressor fans ("core-flow" air), while the rest of the air enters bypass tubes and goes straight to the afterburner (bypass air). The air in the compressor fans is further compressed (and thus further heated), and then fuel is added to it in the combustion chamber - it then reaches the maximum temperature anywhere in the Blackbird, just under the temperature where the turbine blades would start to soften. After passing by the turbine (and thus being cooled somewhat), the core-flow air rejoins the bypass air and goes through the afterburner. However, as the Blackbird reaches higher speeds, the initial shock-cone compression makes the core air start out hotter, before being further heated by the compressor and in combustion, therefore less fuel must be added to the combustion chamber in order not to melt the turbine blades immediately downstream. At around MACH 3, the increased heating from the shock cone compression, plus the heating from the compressor fans, are already enough to get the core air to dangerously high temperatures, and no fuel is added in the combustion chamber. This means the whole compressor-combustor-turbine set-up in the core of the engine provides no power, and the Blackbird flies on afterburners alone, using the compression from the shock cones: the engines become ramjets. No other aircraft does this. One useful way to visualize this is to imagine a turbojet engine sitting inside a ramjet engine. Both the turbojet (engine core) and the ramjet (afterburners running on bypass air) work at lower speeds, but at higher speeds the turbojet shuts down and just sits in the way of the air flowing through the ramjet. (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).

Originally, the Blackbird's engines started up with the assistance of an external "start cart", a cart containing two Buick V-8 engines which was rolled out onto the runway underneath the aircraft. The two Buick engines powered a single, vertical driveshaft connected to a single J-58 engine. Once one engine was started, the cart was wheeled over to the other side of the aircraft to start the other engine. The operation was deafening. In later years, the J58s were started with a conventional start cart.

The red stripes found on some SR-71's are there to prevent maintenance workers from damaging the skin of the airplane.

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 so many feet apart.

Myth and lore

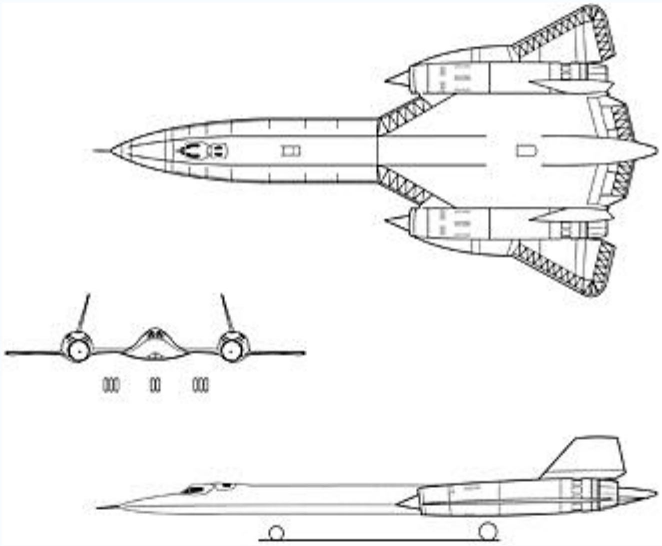
A trainer version of the USAF SR-71. (note the second canopy) The liquid trails on the fuselage are from fuel, splashed on the surface of the aircraft after the refueling boom has been removed from the refueling socket. The fuel trails on the wings are from leaks, sprung from dozens of cracks in the fuel cell, following a fuel load disconnect at non-optimum airspeed.)

The plane has developed a small cult following, given its design, specifications, and the aura of secrecy that surrounds it. Some conspiracy theorists have speculated that the true operational capabilities of the SR-71 and the associated A-12 have never been revealed. Most aviation buffs speculate that given a confluence of structural and aerodynamic tolerances that the plane could fly at a maximum of Mach 3.3 for extended periods, and could not exceed Mach 3.44 in any currently known configuration. Specifically, these groups cite the specific maximum temperature for the compressor inlet of 427°C (800°F). This temperature is quickly surpassed at speeds greater than Mach 3.3. Mach 3.44 is given as the speed at which the engine enters a state of "unstart". Some speculate that the former condition can be alleviated by superior compressor design and composition, while the latter might be solved with improved shock cones.

It should be noted that the SR-71's Pratt & Whitney J58 engines never exceeded testbench values above Mach 3.6 in unclassified tests. Given the history of the plane, the advanced and classified nature of much of its original design, and most importantly, the simple fact that no SR-71 exists in a form that is immediately airworthy, it may never be known what the true design tolerances of the aircraft were, or if these tolerances were ever approached in flight. This unverifiability undoubtedly contributes to the myths and fallacies surrounding the SR-71.

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 look like a flying barn, but its return is more like 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. Furthermore, this is no comparison to the later F-117 whose RCS is on the order of a small ball bearing.

Specifications



General characteristics

- **Crew:** 1 or 2
- **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:** 170,000 lb (77,000 kg)
- **Maximum gross takeoff weight:** 172,000 lb (78,000 kg)
- **Powerplant:** 2× Pratt & Whitney J58-1 continuous bleed-afterburning turbojets; 32,500 lbf (144.57 kN) thrust
- **Wheel track:** 16 ft 8 in (5.08 m)
- **Wheel base:** 37 ft 10 in (11.53 m)

Performance

- **Maximum speed:** Mach 3.35 (1,906 knots, 2,193 mph, 3,530 km/h) at 80,000 ft (24,285 m)
- **Combat range:** 2,900 nm (5,400 km)
- **Ferry range:** 3,200 nm (5,926.4 km)
- **Operational ceiling:** 85,000 ft (25,900 m)
- **Maximum altitude:** 100,000 ft (30,500 m)
- **Maximum rate of climb:** >60 m/s
- **Wing loading:** 94 lb/ft² (460 kg/m²)
- **Thrust/weight ratio:** 0.382:1

Designation sequence:

XB-68 - RB-69 - XB-70 - **SR-71** - XGAM-72 - SM-73 - SM-75

Related development:

- A-12 Oxcart
- Lockheed YF-12
- M-21 drone

Related lists:

- List of military aircraft of the United States
- List of reconnaissance aircraft
- List of Lockheed aircraft

See also:

- Heat shield
- Lockheed YF-12
- LASRE Linear Aerospike SR-71 Experiment
- Aurora aircraft (supposed follow-up to the SR-71)
- Dr. James Gilbert Baker

External links:

- SR-71 Online
- SR-71 Online - Blackbird Image Gallery
- SR-71 Online - Blackbird Diagrams Gallery
- SR-71 Flight Manual
- Blackbird Spotting maps the location of every existing Blackbird, with aerial photos from Google Maps
- SR-71 Blackbird Wallpaper
- The heart of the SR-71 : the J-58 engine
- The Online Blackbird Museum
- Crash site of SR-71 #953 - Crashed on December 19, 1969
- Blackbirds.net page on the A-12 family
- SR-71 Blackbird Links to 72 Internet Sites
- First-hand account of SR-71 maintenance