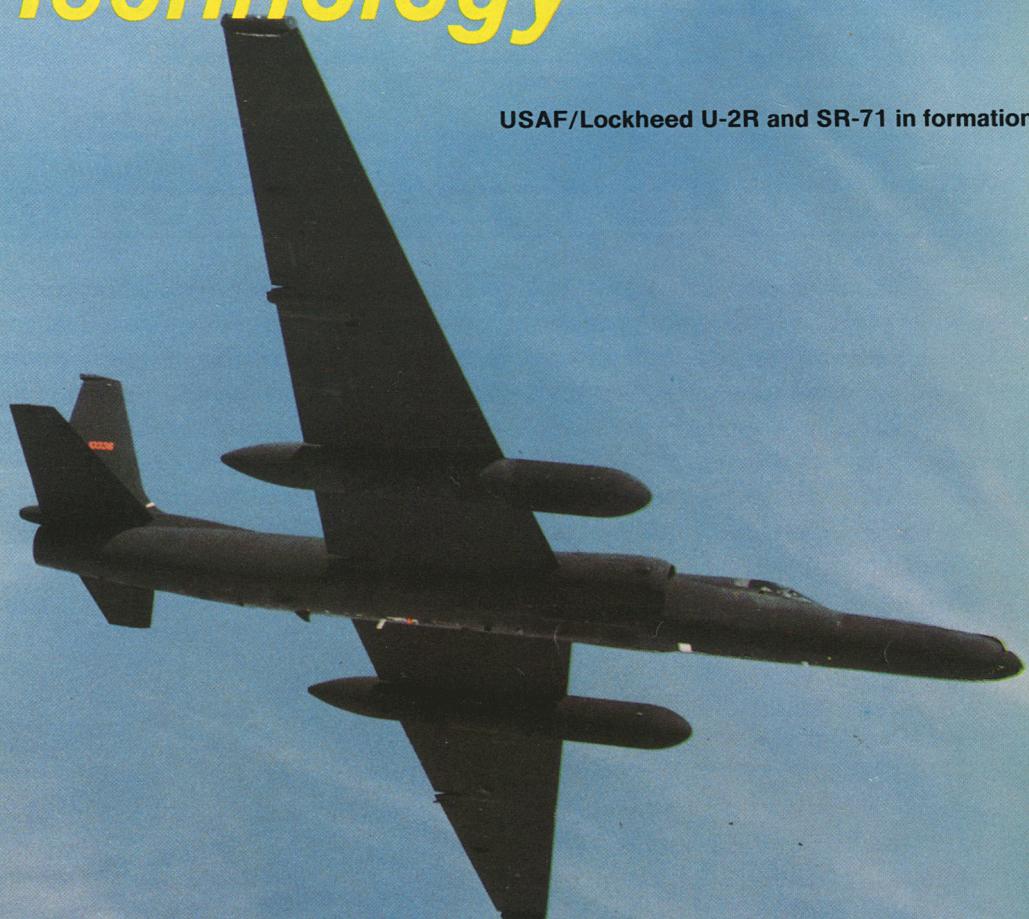


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# Aviation Week & Space Technology

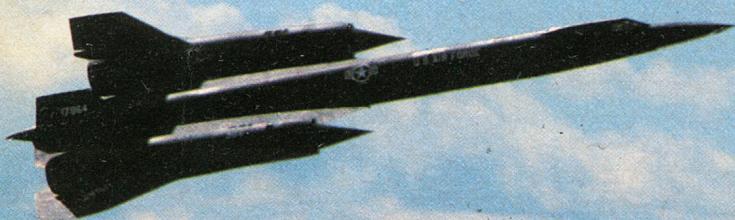
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USAF/Lockheed U-2R and SR-71 in formation



Aviation Week Pilot Report:  
**Lockheed SR-71**

## *Aviation Week Pilot Report*



**Air Force/Lockheed SR-71 strategic reconnaissance aircraft** lifts off runway (below right) at Beale AFB, Calif., afterburners lit, at start of the AVIATION WEEK & SPACE TECHNOLOGY evaluation flight. The SR-71 starts pullup (above left) after low pass following the evaluation flight, and at top the SR-71 accelerates. Large drag chute (above right) slows the aircraft after landing. Chute is deployed on touchdown.

### Cover

U.S. Air Force/Lockheed U-2R tactical reconnaissance aircraft (top) and SR-71 strategic reconnaissance aircraft (bottom) fly in loose formation over southern California's Mojave Desert after joining up at the end of separate test flights from Lockheed's Palmdale, Calif., facility. Note nose-high attitude of SR-71, indicating it is nearing bottom edge of its airspeed envelope, while lower nose attitude of the U-2R suggests it is nearing upper limit of its airspeed envelope. Lockheed-California photo by Robert C. Ferguson.

# SR-71 Impressive in High-Speed Regime

By Robert R. Ropelowski

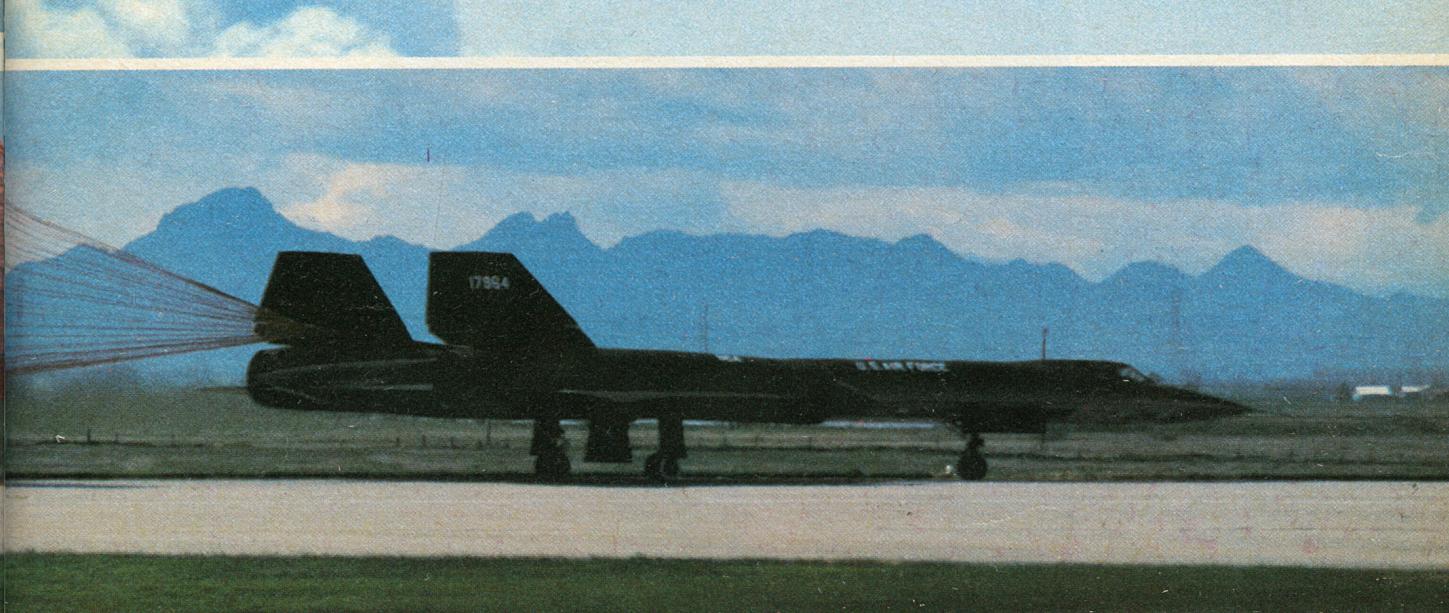
**Beale AFB, Calif.**—Continued improvements to aircraft systems as well as reconnaissance and electronic warfare subsystems in the U. S. Air Force/Lockheed SR-71 are keeping that aircraft a viable and survivable strategic reconnaissance platform after more than 16 years in service.

The SR-71 remains unmatched in its sustained speed and altitude performance despite its aging subsystems and the heavy workload imposed on the crews who operate the Mach 3-plus aircraft. Efforts are under way to update the SR-71's flight controls and displays with newer technology that will improve reliability and reduce crew workload.

The impressive performance and demanding workload

of the SR-71 were experienced first-hand by this AVIATION WEEK & SPACE TECHNOLOGY pilot in a recent flight in the aircraft with the 1st Strategic Reconnaissance Sqdn. of the 9th Strategic Reconnaissance Wing here at Beale AFB. The flight was preceded by two days of briefings and preparation, including a full day in both the front and rear cockpits of an SR-71 simulator.

It was barely enough preparation. The unique high speed, high altitude, high temperature environment in which the SR-71 operates makes for preflight, in-flight and post-flight procedures that are more lengthy and complex than any other aircraft in the Free World inventory. Special life-sustaining support systems are essential before, during and after every flight, and normal and



emergency procedure checklists used by SR-71 pilots and reconnaissance systems operators (RSO) are thicker than any aircraft checklist I have seen in the past.

Despite this, the SR-71 makes flight at Mach 3 and 80,000 ft. seem easy. It was not until 1976, in fact—more than 10 years after the SR-71 entered service—that 9th Strategic Reconnaissance Wing crews from Beale set world absolute and world class speed and altitude records of 2,189 mph. and 86,000 ft. in horizontal flight (AW&ST Aug. 2, 1976, p. 27). These records still stand.

Crew preparations for the AVIATION WEEK demonstration flight began more than three hours before the flight with a high-protein breakfast of steak and eggs in the Physiological Support Div. dining room, which is maintained specifically to meet the special requirements of the SR-71 and U-2 missions.

### Mission Simulation

The day before the flight, typical missions were flown from both the front and rear cockpits in the SR-71 simulator, under the supervision of Maj. B. C. Thomas and Maj. William Keller—instructor pilot and instructor RSO, respectively, in the simulator and the SR-71.

There are no flight controls per se in the rear cockpit of the standard SR-71A, although the RSO can control the horizontal flight path of the aircraft through the astro-inertial navigation system.

Neither the layout nor instrumentation in either cockpit is particularly exotic. A possible exception is the navigation system controls in the rear and the instrumentation in the front cockpit for monitoring and controlling the aircraft's center of gravity and the engine inlet and exhaust systems that provide much of the aircraft's cruise thrust.

B. C. Thomas, who had provided front cockpit simulator instruction, was the pilot for the demonstration flight, while I occupied the RSO position in the rear cockpit.

About 1.5 hr. before takeoff, we went through a brief physical examination, including temperature and blood pressure checks (standard procedure before each SR-71 mission), then began suiting up in full-pressure suits.

Two men are needed to assist the crew-members in donning this suit, and this service was provided by personnel from the 9th SRW's Physiological Support Div. The process took about 30 min., including a final check of the pressurization, breath-

ing, cooling and face-plate heating functions.

We were then transported by van to the aircraft, with hoses available in the van for cooling the inside of the suit. For the transition from the van to the aircraft, portable cooling units were carried.

Each SR-71 is kept in its own individual shelter at Beale, and all preflight checks and engine startup are accomplished in the shelter.

The shelter floor beneath the aircraft was covered with fuel, and it flowed at some points to other areas of the hangar. The SR-71 has six fuel tanks in its fuse-

Because of the fire risks with standard fuels under these conditions, JP-7 fuel with a high flash point is used in the SR-71.

There is no evaporation with JP-7, and a lighted match can be dropped in it without igniting it.

Strapping into the cockpit of the SR-71 with a full pressure suit is a cumbersome process, and Physiological Support Div. personnel routinely accompany crewmembers to assist in this. Once in, we sealed our helmets and began breathing 100% oxygen.

Standard practice in the SR-71 is to breathe pure oxygen for at least 30 min. prior to takeoff to eliminate nitrogen in the body, thus reducing the possibility of decompression sickness at altitude. SR-71 crews normally try to be in the aircraft 50-55 min. before their scheduled takeoff time, with the engines started about 40 min. prior to takeoff.

### Cockpit Entered

Our installation in the cockpit was one of the final steps in a process that had begun hours before for the various support personnel associated with the aircraft. For a typical operational mission, the process begins at least a day ahead. An 18-24-hr. lead time is normally needed to identify, prepare and install the reconnaissance sensors that will be used on a particular mission.

In addition, a mission tape is cut to be installed the day before the mission in the aircraft's astro-inertial navigation system. The tape provides navigation commands to the SR-71's autopilot during the flight and automatically starts and stops sensors and their recorders when the aircraft approaches and passes the ground positions designated for reconnaissance.

With sensors installed and the navigation system programmed, mission payload specialists then begin a checkout of the system about 2.5 hr. before flight. Shortly after this, Physiological Support Div. personnel begin their own checkout of environmental control and life support systems.

Because of the environmental extremes in which the SR-71 operates, a very thick, specially developed oil is used in the aircraft's Pratt & Whitney J58 engines. When temperatures drop below 30°C (86°F), the oil is almost a solid and must be preheated to 30°C before the engines can be started. Normally, this takes about 1 hr. for each 10 deg. the oil must be heated. Special ground carts are required for this



**SR-71 instructor pilot Maj. B. C. Thomas, left, and AVIATION WEEK & SPACE TECHNOLOGY Los Angeles bureau chief Robert R. Ropelewski discuss characteristics of the SR-71 after the evaluation flight.**

lage and wings, but there are no internal fuel bladders as such and the skin of the aircraft serves as the outer wall of the tanks.

Because of airframe expansion and contraction associated with heating of the SR-71's skin at high Mach flight and subsequent ground cooling, it is impossible to keep the fuel tanks sealed (AW&ST June 16, 1980, p. 166). As a result, the tanks leak profusely on the ground, leaving a large pool of fuel beneath and around the aircraft. "It's enough to give a safety officer a heart attack the first time he sees this," Thomas said as we walked around the aircraft.



Air Force/Lockheed SR-71B dual control trainer version of the SR-71 strategic reconnaissance aircraft refuels from a Boeing KC-135 tanker during a training mission over the northwestern U. S. SR-71B is seen below through KC-135 boom operator's viewport as it takes on fuel from the tanker through the refueling boom plugged into the SR-71 behind the rear cockpit.



task, and these were operating as we climbed into the aircraft because the temperature was about 15C (60F).

Prestart checks in both cockpits took 15 min. Because of the high flash point of JP-7 fuel, normal igniters are incapable of igniting it.

Instead, a small amount of triethyl borane (TEB) is injected into the engine combustion chambers using an air turbine starter plugged into the bottom of each engine nacelle once engine rpm. has built up. The triethyl borane ignites on contact with the JP-7 and causes the fuel to ignite as well.

The TEB also is used for each afterburner ignition and for engine air starts (AW&ST May 10, 1976, p. 93).

Once the first engine was started, it was necessary to wait 2 min. to insure that the engine's hydraulics were operating properly before any hydraulically actuated systems or flight controls could be operated. Controls were then checked and the second engine was started. Additional checklist items took another 15 min. before we were ready to taxi.

### Brake Malfunction

As the aircraft rolled out, Thomas applied the brakes only to find that the pedals went to the floor with no brake response. A quick recycling of the hydraulic system selector switch in the front cockpit brought pressure, however, and we continued taxiing toward the runway.

Our flight plan called for an unrefueled mission that took us from central California over Nevada and Idaho, then back across Idaho and over Oregon before returning to Beale.

Although it was partly cloudy as we taxied to the runway, I selected the astro-navigation function on the astro-inertial navigation system in the rear cockpit. Within a few seconds, a white star illuminated on the mode selector button, indicating

that the system had located and was tracking at least three stars in its preprogrammed catalog of 52 stars.

A chronometer in the navigation system is programmed with the day of the year and the time of the day, accurate to 5 millisec., and thus knows which stars to look for from any location and at any given time. A star tracker mounted on gimbals takes periodic sightings that are then fed into a digital computer to correct the aircraft's position as determined by the system's inertial reference unit.

The navigation system, mounted in a space in the upper fuselage just behind the RSO's cockpit, thus provides the reconnaissance aircraft with precise navigation without relying on any external radio emission. Had clouds prevented the star tracker from getting an accurate fix while we were still on the ground, the inertial system would have continued to provide navigation guidance until we were above the clouds and star tracking was possible.

Remaining items on the takeoff checklist were completed in the run-up area beside the runway. Thomas held the brakes and ran the throttles up to military power (maximum power without afterburner) on one engine at a time for an engine trim check. Unlike most other turbine engines, the Pratt & Whitney J58 can be trimmed from the cockpit of the aircraft—either automatically or manually.

With the trim switches in the automatic position during the run-up, Thomas monitored the exhaust gas temperature/rpm. relationship on each engine to insure that it conformed with the figures on his checklist. EGT was monitored throughout the flight to make sure there was no significant variation between the two engines.

Once this and the remaining checklist items were completed, we taxied onto the departure runway. Thomas advanced the throttles to military power but held the

brakes until getting an indication that the movable inlet guide vanes on the J58s had shifted from the axial (full open) position to the cambered position (partially closed, to turn incoming airstream at the compressor face). He then released the brakes and pushed the throttles into the afterburner range. The left burner ignited about one-half sec. ahead of the right one, resulting in a snap to the right, noticeable in the cockpit. An ignition lag of up to 5 sec. is acceptable between the two afterburners.

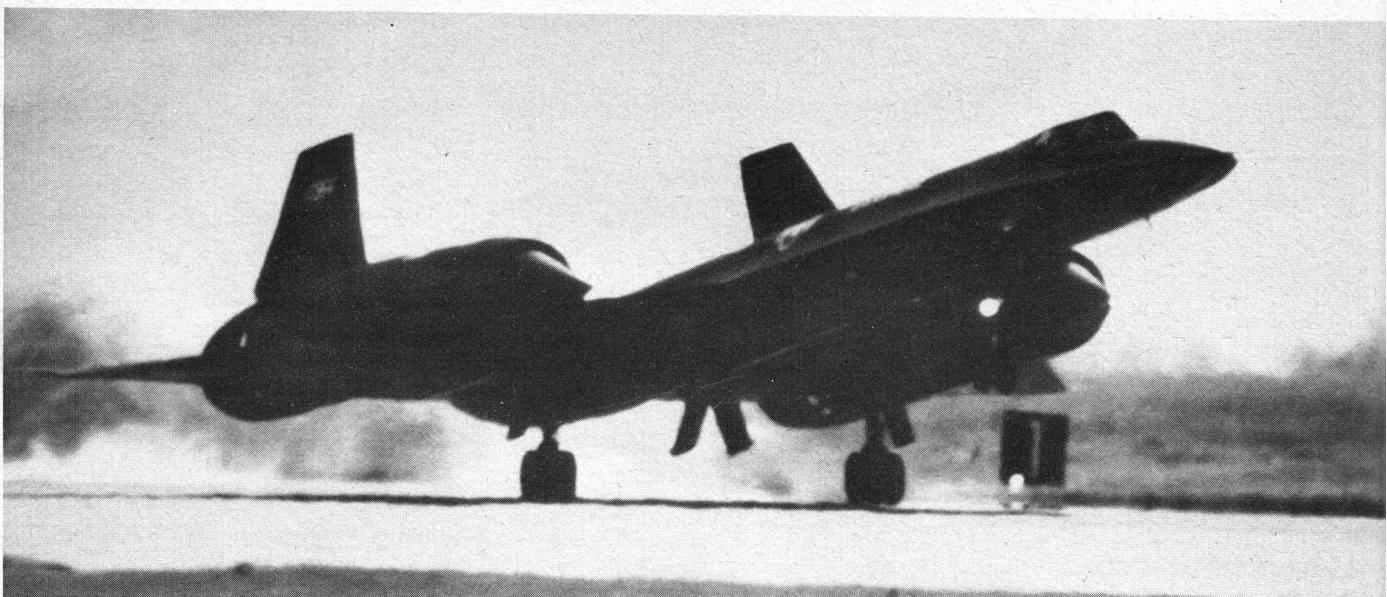
Aircraft weight at that point was in excess of 100,000 lb., including about 50,000 lb. of fuel. With the two J58 engines producing a combined total of about 68,000 lb. thrust, the aircraft accelerated quickly. At 180 kt., Thomas raised the nose of the aircraft to a deck angle of about 15 deg., and the SR-71 lifted off at about 210 kt. after a takeoff roll that took about 20 sec. and covered approximately 4,300 ft.

### Landing Gear Limitation

The SR-71 has a 300-kt. landing gear extension limitation, and the aircraft reaches that speed quickly after liftoff. The landing gear retraction cycle, on the other hand, seems to be rather slow, sometimes necessitating a power reduction to keep the airspeed below 300 kt. until all gear units are retracted fully.

I had experienced this in the simulator the previous day. Thomas faced the same problem on takeoff in the aircraft, and he was just about to reduce power as the airspeed nudged 300 kt., when the landing gear finally gave a full-up indication.

Although an aerial refueling was not included in our flight, we leveled off at 25,000 ft. as if we were going to refuel from a tanker. At 400 kt. equivalent airspeed (KEAS) the climb to 25,000 ft. was accomplished quickly, with the aircraft climbing at a rate of approximately 10,000



**SR-71 touches down at Beale AFB for a touch-and-go landing during the AVIATION WEEK & SPACE TECHNOLOGY demonstration flight. At typical landing weights such as the aircraft was at in this photo, landing speed is generally around 150-155 kt.**

fpm. We leveled off at that altitude, holding 400 kt.

While we waited for clearance to a higher altitude, Thomas pulsed the controls with the stability augmentation system (SAS) on and off. Pitch, roll and yaw oscillations were damped almost immediately with the SAS on, and the aircraft showed no unfavorable tendency to diverge from its normal attitude. With the SAS off, the pulse-induced oscillations continued for at least five to six cycles before slowly damping out.

### Simulated Failure

In the simulator, I had experienced an SAS failure while cruising on instruments at Mach 3 and 80,000 ft. Chasing the nose of the aircraft with the stick under these circumstances resulted in a pilot-induced oscillation that ultimately led to 90-deg. nose pitch-up and loss of control of the aircraft.

Because of the reduced pitch stability margin at high speeds, a pitch boundary indicator in the form of an index on the left side of the indicator is incorporated in the front cockpit. The same index is used on many other aircraft to present raw instrument landing system (ILS) glide-slope data. The pitch boundary indicator is controlled by both angle of attack and pitch rate inputs. In the event of stability augmentation system malfunction, the pitch boundary indicator and the pitch steering bar on the flight director attitude indicator become the primary pitch references. A stickshaker and stickpusher are also associated with the pitch control system.

In the roll and yaw axes, surface limiter switches are incorporated to prevent excessive control travel.

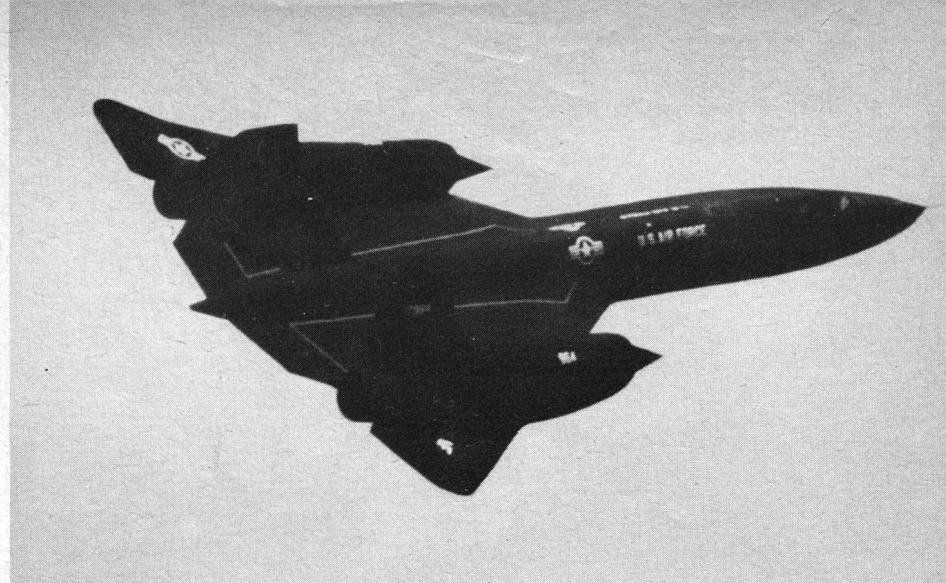
Roll limits are applied at the stick itself, while yaw controls are imposed at the rudder servos. The surface limiters are manually engaged through switches in the cockpit that are turned on at 0.5 Mach during acceleration.

### Stability System

Because of the pitch and yaw instabilities, the SR-71 is equipped with an elaborate three-axis, eight-channel stability augmentation system that automatically compensates for many of the aircraft's natural instabilities.

At the same time, however, the SR-71 is limited to a conservative bank angle even with the SAS engaged. This can be increased slightly with the autopilot engaged. Until they have logged 60 hr. in the aircraft, SR-71 pilots are restricted to shallow bank angles.

After several minutes at 25,000 ft., we were cleared to continue our climb and accelerate to Mach 3. Thomas advanced the throttles into the afterburner range, and there was a sudden slight yaw to the right as the afterburners ignited asymmetrically again. Pulling the nose up about 10 deg., Thomas kept our speed at 0.9 Mach



**SR-71 banks hard right at low altitude over Beale AFB runway at the end of a low-altitude, gear-up pass down the runway. Despite its size and weight, the SR-71 showed a surprising agility at low speed and low altitude in the landing pattern at Beale, even during single engine approaches and go-arounds.**

until we passed 30,000 ft., then adjusted the aircraft attitude for a slow acceleration to 0.95 Mach at 33,000 ft. Our rate of climb at that point was over 6,000 fpm.

Because the highest drag, and therefore the greatest fuel consumption, is in the transonic regime, SR-71 crews try to get through it as quickly as possible by performing a "dipsy" maneuver. Just before reaching 33,000 ft., Thomas pushed the nose down slightly to pass through Mach 1 and accelerate to 450 kt. at a steady descent rate of 2,500 fpm. He then pulled the nose up to continue the climb at 450 kt. as the Mach number slowly increased.

There was no sensation or unusual aircraft reaction as it passed through Mach 1.

From this point on, Thomas was busy monitoring the various fuel, engine and engine inlet systems used on the aircraft to control its center of gravity, keep the engines running at maximum efficiency and increase the thrust of the propulsion system.

The fuel system had pumped fuel aft automatically during the acceleration to supersonic speed to shift the center of gravity rearward in order to balance the shift in aerodynamic forces. Because the aircraft cannot be flown to its maximum cruise speed without complete control of the center of gravity, two manual backup systems are incorporated to accomplish this function in case the automatic controls do not work. Thomas said, "More often than not, we have to play with it."

The SR-71 uses mixed compression, axially symmetric inlets and a free-floating exhaust nozzle system to control airflow in and out of the engines. The functioning of these systems is such that a turbo-ramjet phenomenon occurs in which the inlets and exhaust nozzles produce most of the thrust at cruise speeds.

At Mach 1.4, bypass doors around the

forward portion of the engine nacelles began automatically to modulate the flow of air to the engine compressors. Forward and aft bypass doors are located in front of the compressors, with the forward doors spilling inlet air overboard when necessary and the aft bypass doors venting excess inlet air around the engine and into the exhaust nozzle, where it produces more thrust.

At Mach 1.7, Thomas selected the "A" position for the aft bypass doors, opening them slightly. Also at Mach 1.7, the "spikes" or cones protruding from the center of the nacelles begin retracting into the nacelles to control the shock wave that forms in front of the engine compressors when the aircraft is at supersonic speeds. The spikes move aft when the aircraft reaches its maximum cruise speed.

### Shock Wave

Between them, the spikes and the forward and aft bypass doors keep the shock wave trapped inside the nacelle and ahead of the compressor, allowing air to enter the compressor at subsonic speeds.

At Mach 2-2.1, the variable position inlet guide vanes on the engines translate from the axial to the cambered position to maintain a constant inlet pressure on the compressor face. The pilot must engage a lockout switch at that point to prevent the inlet guide vanes from returning to the axial position. Without the IGV shift, speed is limited to about Mach 2.

At Mach 2.6 and 450 KEAS, the autopilot, if engaged, begins to follow an airspeed bleed schedule that reduces equivalent airspeed by 1 kt. for each incremental increase of 0.01 Mach.

By Mach 2.7, the aft bypass doors in the inlets were nearly fully closed again to meet the ram air requirements of the engines at that speed.

All of these steps have to be either

monitored or accomplished manually by the pilot. Given the rate at which the SR-71 accelerates, this means that the pilot is extremely busy during the acceleration to cruise speed and the climb to altitude. As we pass 70,000 ft. at Mach 2.99, the SR-71's climb rate was still above 1,000 fpm.

When the inlet and exhaust systems are working properly, they produce up to 90% of the SR-71's thrust at cruise speeds, according to Ben Rich, Lockheed-California Co.'s vice president of advanced development projects (Skunk Works). Rich was one of the designers of the SR-71 and its complex propulsion system.

### High Altitude Performance

"At high altitude, the engine becomes a supercharged ramjet," Rich said. "At cruise speeds, 60% of the thrust comes from the inlets, which act as superchargers in front of the engines. The engine is simply an air inducer at that point."

In the exhaust nozzle, Rich said, air comes out of the turbojets at essentially the same speed it went in. "We designed the ejectors with convergent/divergent nozzles that reaccelerate the air to as close to cruise Mach as possible. The aircraft gets 30% of its cruise thrust from the ejectors. That means the engines are producing only 10% of cruise thrust."

Because of this, a malfunction or failure in the inlet or exhaust systems has the same effect as the loss of an engine on an aircraft with wing-mounted engines. An inlet "unstart," where the shock wave becomes unstable and is expelled from an inlet, is at least as dramatic as an engine loss on any twin-engine aircraft.

### Drag Increase

When one of the inlets malfunctions and the thrust it produces is lost, there is an immediate sharp increase in drag that causes the aircraft to yaw briskly in the direction of the malfunctioning inlet. I had experienced an unstart in the SR-71 simulator, but there the sudden yaw was restrained to a mild "kick" by the simulator. In the aircraft, however, the reaction can be severe enough to dash the crew's helmets against the canopy with considerable force.

Although the SAS and autopilot take care of the immediate need to apply corrective control inputs, an unstart is still a two-page emergency checklist event in the pilot's handbook because of the large number of subsystems that can cause an unstart.

Recovery must be made fairly quickly to avoid having to descend from altitude and abort the mission. Provisions are included in the propulsion control system for a sympathetic unstart and restart of the other engine to restore symmetry to the aircraft's flight controls.

During our acceleration and climb, a low rumble or buzzing developed around Mach 2.2 that could be heard and felt in



Air Force technicians from the 9th Strategic Reconnaissance Wing's Physiological Support Div. assist Ropolewski in connecting his pressure suit inside the rear cockpit.

the airframe. Thomas said it suggested the onset of an inlet unstart, and he suggested bracing for such an event. There was, however, no indication on the propulsion system instruments of a malfunction, and the buzzing subsided after 1-2 min. Rich suggested that the buzzing was caused by the boundary layer separating and reattaching in one of the inlets, which sometimes happens between Mach 2.2 and 2.5.

Shortly after this, we leveled off just above 80,000 ft. and at a speed slightly in excess of Mach 3, with an airspeed of around 330 KEAS. Thomas brought the throttles back to the minimum afterburner range, where they remained for the cruise portion of our flight.

The center of gravity at this point was at 25% mean aerodynamic chord, compared with 19% at subsonic speed. The cg. shift was accomplished automatically during the climb and acceleration phase.

At our cruise altitude, the curvature of the Earth was readily apparent, and the sky above was a very dark blue. Despite the thin air, there was enough friction on the aircraft to generate a substantial amount of heat.

Surface temperatures range from 400 to 1,200°F at various spots on the aircraft's exterior during prolonged flight at Mach 3. Around the cockpit itself, the temperature reaches about 530°F. This heat could be felt through the narrow windows of the rear cockpit, even while wearing the relatively thick pressure suit gloves. Temperatures on the wing and fuselage skin that forms the outer wall of the aircraft's fuel tanks get even hotter than they do around

the cockpit, and a nitrogen inerting system is used to reduce the possibility of fire in the tanks. The nitrogen is injected directly into the fuel cells from Dewars carried inside the aircraft.

While the sensation of speed is generally lacking in most high-flying jet aircraft, the cruise speed of the SR-71 is such that its rapid movement was apparent even from 80,000 ft. when judged by the broken cloud layer 50,000-60,000 ft. below us. Groundspeed at that point was above 30 mi./min. Thomas had engaged the autopilot when we began our climb out of 25,000 ft., and that, coupled with the astro-navigation system, held us closely to our preplanned course.

### Accuracy Checks

Within its capabilities, the system checks its own accuracy and displays the deviation from course in one of the windows of the ANS control head in the rear cockpit. The deviation is presented in tenths of a mile right or left of course. Except when the aircraft was being hand flown, the course error window generally showed all zeros. In the front cockpit, course deviations are indicated by deflections of the course deviation bar on the attitude director indicator. Full deflection of the bar either right or left indicates the aircraft is 1 mi. off course.

"We start to get nervous when we're just a little off course," Thomas said. "The ANS generally flies the black line," he added, referring to the system's ability to navigate accurately a course drawn with a black line on a map.

Thomas and other SR-71 crewmembers

said it is possible to get lost quickly at Mach 3, and so careful attention is paid to the aircraft's position throughout each flight.

Fuel requirements are a major factor in mission planning and are based on the assumption that the aircraft will follow the designated course. There is little margin for error. Thus, even when getting lost is not a consideration, any deviations from the planned course can add significantly to fuel consumption and jeopardize the successful completion of the mission.

### Flight Plan

Pilot and RSO in the SR-71 both carry a detailed flight plan for each mission that lists normal flight planning information such as en route times and estimated arrival times over en route navigation fixes as well as specific bank angles to be used and the schedule for the operation of the various reconnaissance systems on the aircraft. The RSO monitors all of these and checks them against the estimated en route and arrival times, waypoint information, groundspeed and course deviation indications provided by the astro-inertial navigation system. All times on the plan are listed in minutes and seconds.

Other factors besides course deviation can affect fuel consumption, and the crew's monitoring function is continuous. The inlet spike for each engine, for example, is controlled automatically by an air data computer according to the aircraft's speed. If the spikes are as little as one-half in. out of position for a given speed, fuel flow could increase significantly enough to necessitate aborting the mission. Spike position indicators in the front cockpit are monitored by the pilot throughout the flight, and the spikes can be positioned manually by the pilot if the automatic system malfunctions.

Likewise, center of gravity control is also critical to fuel efficiency in the SR-71. Rather than using the elevons to trim the delta-wing aircraft, fuel is pumped forward or aft to shift the center of gravity, allowing the elevons to be kept in a minimum drag position. A 1% error in center of gravity location from the optimum can result in a mission abort for low fuel, Thomas said.

"It's really incumbent on the pilot to take a great deal of care in how the aircraft is flown," he said.

As we passed to the south of Boise, Idaho, the aircraft banked to the left in a programmed 180-deg. turn that took us to the east and then to the north of the city before the turn was completed. At Mach 3, the SR-71 does not turn very quickly, and at a bank angle of 30 deg., our 180-deg. turn described a semicircle around Boise with a diameter of about 170 mi.

The turn took long enough to allow me to sample the specially packaged foods carried by SR-71 crews on extended missions. A soft plastic bottle with water, a

tube of apple sauce and a tube of pureed peaches had been stowed in the rear cockpit before the flight. A special cap with a relatively thick plastic straw comes with each tube, and the water bottle also has an integral plastic straw in the cap.

These straws are inserted through a small hole at the base of the pressure suit helmet, then pushed into the mouth. The water bottle or the tubes are then squeezed to take nourishment. The technique worked well enough, although the system does not make provisions for inserting a napkin to wipe the peach residue off the crewmember's chin and off the inside of his mask. The hole at the base of the helmet was self-sealing once the straws were removed.

Shortly after the aircraft completed the turn and was heading back toward the west, Thomas retarded the throttles to military power from the minimum afterburner position and we began a descent. Engine and inlet limitations at high speed and high altitude are such that the SR-71 has a very narrow descent "throat" through which it must be flown when leaving cruise altitude. The engines are kept at military power—maximum power without afterburners—and airspeed is kept at 350 kt. minimum to avoid inlet disturbances.

"The throttle schedule is locked in once we start our descent," Thomas said. "Mach 1.3 is the first point in our descent and deceleration where we can do anything to adjust the descent profile."

### Descent Rate

The descent/deceleration profile began moderately with a descent rate of about 400 fpm. and a slight deceleration rate. Our speed was still at Mach 2.5 at 70,000 ft. and Mach 2 at 60,000 ft. Because the precise altitude capabilities of the SR-71 are still held secret, common procedure for Air Force crews is to turn off the Mode C altitude reporting function of the aircraft's transponder above 60,000 ft. I had done this on our climb to altitude, and conversely, turned it back on again as we descended below that altitude on our return. The rate of descent had reached 3,500 fpm. by 60,000 ft. and was at 5,000 fpm. when we passed through 50,000 ft. at about Mach 1.6.

At around 31,000 ft., the aircraft's speed dropped below Mach 1, and the nose pitched up slightly from a 15-deg. nose-down attitude to about 5 deg. nose down. Our equivalent airspeed at that point was still about 365 kt.

Throughout the descent, Thomas had been monitoring center of gravity, inlet spike and bypass door movements, and engine behavior in approximately the reverse order from our earlier climb and acceleration. Once we had slowed to subsonic speed, the workload decreased and it was possible to fly the SR-71 more like a conventional aircraft.

With the autopilot still engaged, I

selected waypoint No. 10 in the ANS—the coordinates for Beale AFB—and pushed the "direct steer" button on the ANS control head.

The aircraft turned from its westerly heading to a more southerly one, heading directly toward Beale, which was still about 80 mi. away. Had Thomas been flying manually, he could have followed the ANS-generated flight director steering commands on his attitude director indicator to establish the proper heading for the return to Beale.

While passing through a layer of broken clouds between 15,000 and 10,000 ft. during our descent, some light turbulence was encountered that demonstrated the structural flexibility of the SR-71.

The center of gravity of the aircraft is located in the same general location as that of the landing gear, roughly at the midpoint of the aircraft's 107.4-ft. overall length. The cockpit is approximately 50 ft. in front of this.

### Light Turbulence

In light turbulence, the effect in the cockpit was like sitting at the end of a diving board, bouncing up and down several times during each patch of turbulence. It was not particularly uncomfortable. SR-71 crews have seen significantly more pronounced oscillations in more severe turbulence, according to Thomas.

Once in the landing pattern at Beale, the SR-71 behaved like a conventional aircraft, and even showed a surprising ease of handling that belied its size.

Thomas flew a tight pattern to an initial low pass, an approach and go-around with a simulated engine failure, a touch-and-go landing and a final landing. Airspeed was

kept around 250 kt. in the pattern, slowing to 180 kt. on final.

For the engine-out demonstration, Thomas brought the right engine to idle. There was little yaw associated with the loss of thrust on the right wing because the stability augmentation system automatically applied corrective rudder inputs. The left wing was also lowered about 10 deg. to minimize drag.

The aircraft was much lighter now, and less than military power was needed on the left engine to maintain speed and altitude in the pattern.

For the go-around in this condition, the left afterburner was selected at about 300 ft., necessitating a steeper left bank of about 20 deg. to maintain our track down the runway.

The SAS again took care of corrective rudder inputs, and Thomas kept his feet on the cockpit floor during the climbout and downwind turn.

A conventional touch-and-go and then a final landing followed. Although the long fuselage and large rudders of the SR-71 can pose some difficulties in high cross-winds, crewmembers said the aircraft is not generally a difficult one to land. Our own landings appeared to be fairly routine.

A nose-up attitude of about 8 deg. was held on the downwind leg, increasing to 9 deg. on base, 10 deg. on final and about 12 deg. for touchdown. Forward and peripheral visibility remains good throughout the approach.

The delta wing of the SR-71 generates a considerable amount of ground effect as it nears the runway, helping to soften the landing. Both our touch-and-go and full-stop landing were exceptionally smooth.

Once we were on the ground, Thomas deployed the drag chute that is towed in the upper rear fuselage between the canted rudders. This provides an approximate 0.5 g deceleration force, and brought us forward slightly in our seats. The chute must be released from the aircraft before slowing below 60 kt. in order to avoid getting it tangled in the rudders. This was done, and we slowed to taxi speed with a considerable amount of runway remaining.

Our total flight time was 1.4 hr., during which we covered about 1,800 mi. as well as four circuits of the landing pattern.

From the pilot's point of view, there is a glaring paradox in the SR-71 in terms of the late 1950s/early 1960s technology used in the cockpit to manage a system whose performance is still considered advanced in the early 1980s.

### Improvement Programs

Recognizing this, the Air Force has several improvement programs under way to modernize flight controls and systems in the aircraft, with the aim of improving reliability and thereby reducing cockpit workload for SR-71 crewmembers.

One of the main improvements will be a digital automatic flight and inlet control system that is being flight tested and is expected to appear on operational SR-71s in August.

The new system will integrate the functions of several separate older units, including the present older-generation central air data computer, analog air inlet computers that control the spikes and forward bypass doors, the present autopilot, stability augmentation system and automatic pitch warning system. □