LOCKHEED A-12

The CIA's Blackbird and other variants

PAUL F. CRICKMORE

AIR VANGUARD 12

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INTRODUCTION

Sir Sydney Camm, the renowned British aerospace design engineer, once remarked, "All modern aircraft have four dimensions: span, length, height and politics." In this particular instance, he was referring to the British-built BAC TSR-2; but this fourth, political, dimension exerted an almost exponential influence throughout the development and operational life of Lockheed's aviation icon.

Built by Lockheed to replace their earlier, high-flying, subsonic, reconnaissance-gathering U-2, the A-12 and its stablemate, the SR-71, catapulted high performance into a different orbit. They remain the fastest and highest-flying jet-propelled operational aircraft ever, cruising in afterburner at the designed speed of Mach 3.2 (that's 1.8 miles per second) and at altitudes in excess of 16 miles. However, the political sensitivity surrounding the "Black World" strategic reconnaissance mission caused US President Dwight Eisenhower to insist that such vital covert business should be conducted by an aircraft not only immune from interception, but also blind to hostile radar detection. This necessitated the development of a range of radar "camouflaging" techniques that today we have all come to know as "stealth." But when CIA U-2 pilot Francis Gary Powers was shot down by a surface-to-air missile (SAM) whilst in the middle of a deep-penetration reconnaissance sortie of the Soviet Union on May 1, 1960, politics came to the fore and the fallout would have a profound impact on all such future US aviation programs.

DESIGN AND DEVELOPMENT

During the early-to-mid Cold War years, western leaders had to rely primarily upon reconnaissance aircraft to gather photographic intelligence (PHOTINT), electronic intelligence (ELINT), and communications intelligence (COMMINT) about the activities of the Soviet Union, her allies in the Warsaw Pact, and Communist China. This was in part due to the closed nature of these societies, but also to the size of the land mass and the level of technical ability prevailing at that time. The violation of a sovereign state's airspace is contrary to international law. As a result, such planned incursions required prior clearance from the very top; and in the case of the United States, that meant the President. Routes and the number of sorties were highly regulated and the flights themselves were conducted under conditions of great secrecy. The name

Article 130 (60-6933) seen taxiing from its hangar at Area 51. Early operational configuration of the A-12's paint scheme saw black paint applied only to the chine, nose and cockpit areas. (Lockheed Martin)

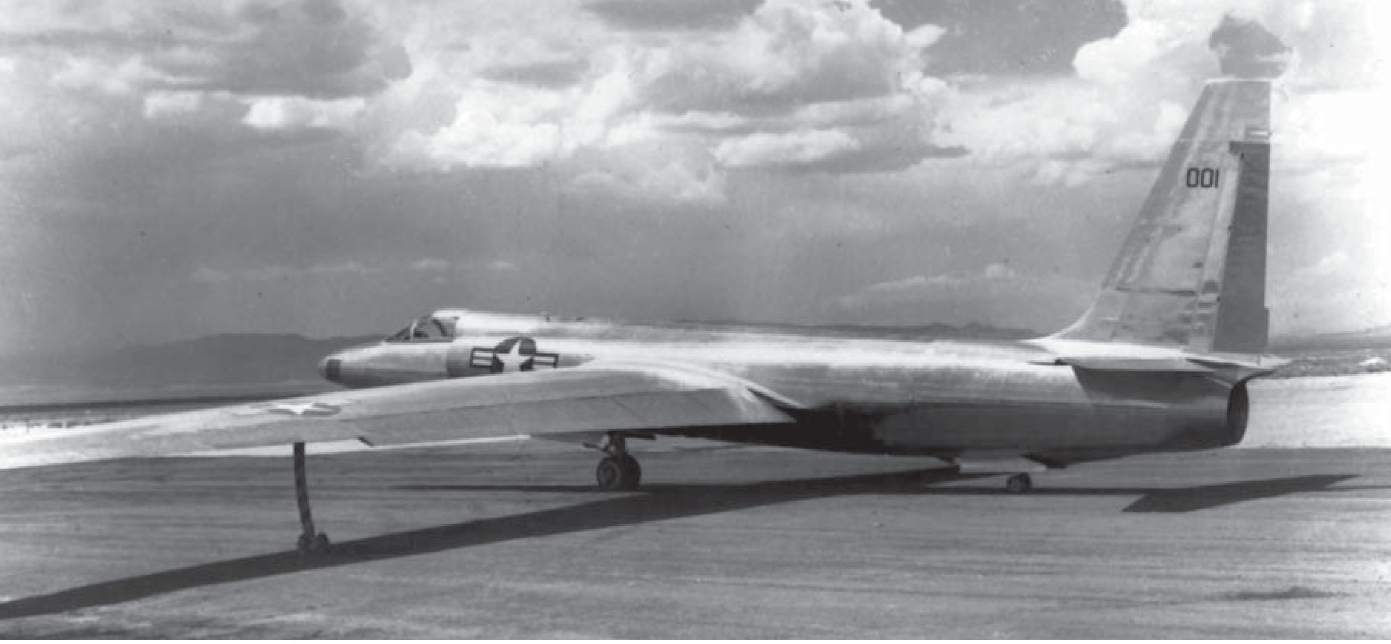
of the game was to acquire the requisite raw data, but avoid at all costs getting caught in the act.

Lockheed's custom-built strategic reconnaissance-gathering aircraft, the U-2, undertook the first in a series of vital but hazardous overflights of "denied territory" on June 20, 1956. Designed by Clarence L. "Kelly" Johnson, President of Lockheed's legendary Skunk Works, and operated by the Central Intelligence Agency (CIA), the program went under the classified cryptonym of Aquatone (later redesignated Chalice). Photographic results gained by the project were sensational. Flying at altitudes in excess of 70,000ft, the frail, subsonic, glider-looking aircraft was immune from fighter interception. But President Eisenhower was concerned that the U-2 should also escape detection and tracking by Soviet radars.

On July 10, 1956, after just five incursions, the Soviets delivered their first protest note about the flights and Eisenhower ordered their immediate suspension. However, those missions had generated a vast amount of intelligence, revealing for the first time many aspects of Soviet military and industrial capability. During a meeting on July 19, and despite pleas to the President from the CIA's Director of Central Intelligence (DCI), Allen Dulles, that Aquatone should be allowed to continue such overflights on the basis that the quality of intelligence gained far outweighed any potential damage to international relations, Eisenhower remained resolute and the ban stood – at least for the immediate future.

On August 16, 1956, the DCI's Special Assistant for Planning and Coordination, Dr Richard Bissell, convened a meeting with Kelly Johnson and a number of prominent scientists – the meeting's objective was to agree on a plan to develop some form of "electronic camouflage" that would render the U-2 invisible to Soviet radars, thereby addressing Eisenhower's concerns. The meeting lasted into the early hours and resumed again at 0700hrs the next day, and by midday they had devised a program to apply radar-canceling devices to a U-2, codename Project Rainbow. It was the first attempt to make an operational aircraft "stealthy." Dr Edwin Land, of the Massachusetts Institute of Technology (MIT), chaired the project and via Marshall Holloway, Director of the MIT Lincoln Laboratory, in Lexington, Massachusetts, recruited a small number of radar experts into the program. They were based in a secure building on the roof of the Lincoln Laboratory and included Frank Rodgers, associate head of the Radar Division.

A major problem facing the team was that during the course of a U-2 overflight, the aircraft would first need to remain invisible to Soviet long-range,



Lockheed Article 341, the U-2 prototype, completed its first flight from "Watertown Strip" – Area 51 – on August 1, 1955. Its contribution to US intelligence gathering continues to this day. (Lockheed Martin)

low-frequency, early warning radars operating in the 65/86 MHz range. Then, upon penetrating deeper into the USSR, high- frequency S-band and X-band target acquisition radars operating in the 2–4 GHz and 8–12 GHz bands respectively, would need to be dealt with. This required the development of different methods and materials to defeat the different radar systems illuminating the target.

By the summer of 1957, the team had developed a number of innovative solutions. To reduce low-frequency returns, the U-2 utilized a system of wires and ferrite beads mounted on the aircraft's vertical tail surface, which were also arranged to frame the aircraft's planform. Known as "Trapeze" and "Wires," this arrangement reduced the U-2's radar return by about 12dB, which in practical terms meant that long-range detection was halved. To reduce returns in the high-frequency bands, radar-absorbent material (RAM) was applied to the underside of the aircraft's fuselage. Operating on the principle of a Salisbury screen, the coating consisted – from the inside out – of fiberglass, a honeycomb spacer, a graphite-impregnated layer, a protective layer for durability, and finally a layer of paint. This treatment was nicknamed "Wallpaper" and aircraft equipped with these devices were known as "Dirty Birds." However, one of the problems resulting from these measures was that they added both weight and drag to the U-2, reducing its maximum altitude by some 5,000ft and its range by about 20 percent.

During a meeting at the White House in early May 1957, preliminary approval was granted for more Soviet overflights, despite the fact that phase one of Project Rainbow hadn't yet been completed. So in June one Dirty Bird was deployed to each of the three U-2 Operating Locations (OLs). Two penetration flights of the Soviet Union were made from Turkey on July 21 and 30 to evaluate the effectiveness of the treatment. But despite "Trapeze," "Wires," and "Wallpaper," subsequent analysis of the U-2's System 5 (a multi-band radar recorder) revealed that Soviet radars had been alerted to the aircraft's presence when it was flying directly toward or directly away from the radar head. This led to the conclusion that the source of the radar returns had emanated from the U-2's inlets, cockpit, and exhaust – none of which could be treated with what had been developed thus far. Clearly, a more radical approach to solving the problem was required.

Frank Rodgers at the Lincoln Laboratory was certainly up for a radical approach. He returned to basic research in a bid to understand the relationship between a radar return and the physical shape of the target without regard to the aerodynamic practicality of such shapes. To his surprise he discovered that if a metal saucer shape was treated by layering circular sheets of Teledeltos paper (a paper with a constant resistance) on top of the shape, with the first sheet of greatest diameter and each successive sheet smaller, by the time the sixth sheet was positioned, resistance was down to 300 ohms – the same as in free space through which the radar wave was moving. This prevented reflections completely, effectively rendering the shape invisible to radar! Rodgers had produced a "broad-band" treatment that was effective against any radar operating at any frequency within a very broad range of frequencies. This was in contrast to the "narrow-band" techniques that had been developed and applied to the Dirty Birds, whereby if a radar was encountered operating at a frequency different to that for which the treatment was designed, its effectiveness was significantly reduced. Unfortunately the shape of the vehicle was completely aerodynamically unstable; but Bissell was extremely impressed and both Rodgers and Norm Taylor were instructed to present the findings to Johnson. But the Skunk Works boss sent the two hapless scientists away with a flea in their ear. Rodgers and Taylor decided that it wasn't the idea that had been wrong, but their presentation. In future, they wisely decided, they would leave the final design of the aircraft to Johnson and instead feed him guidelines that he could incorporate to reduce its radar cross-section (RCS).

Back at the Lincoln Laboratory, concern was being expressed in some influential circles that work being conducted by Rainbow for the CIA was inappropriate. So, in October 1957, it was moved out to a building in Cambridge, Massachusetts, where it was incorporated into the Scientific Engineering Institute (SEI), a Boston-based CIA proprietary. The move also prompted some changes within the team, but Frank Rodgers stayed.

Johnson of course had his own team of electronic engineers back at the Skunk Works. Headed up by Luther Duncan "LD" MacDonald, the team also included Perry Reedy and physicist Ed Lovick. Ed recalls, "Kelly thought that an aircraft made of plastic materials might have sufficiently small low-frequency radar backscatter to defeat the 70 MHz early warning radars. I warned him that it would not and that you'd see the internal structure, the square corners it formed and the fuel. But Kelly wanted to test it anyway. Despite the fact that it was known that practical fiberglass structure would be dense enough to scatter 4in S-band radar waves, he still hoped that an all-plastic airframe might not backscatter 14ft wavelengths significantly. Engine, landing gear parts, and any other metallic items were to be hidden by an, at that time, unspecified means:

> Several all-fiberglass models that incorporated appropriate internal plastic structures were built and tested. One model was a one-eighth scale and was too large for indoor testing, so it was tested at Indian Springs AFB.
>
> Backscattering measurements showed that the thick plastic sections required for strength, and especially corners, were very reflective. When kerosene fuel was added to the interior of the wings, the reflections increased and became characteristic of a solid piece of plastic. When the fuel in partially filled tanks was vibrated and standing waves occurred, the backscatter increased even more.
>
> After attempts to hide the structure, fuel and simulated engines yielded poor results, Kelly agreed to abandon that idea.

Lockheed Skunk Works boss, Clarence L. "Kelly" Johnson, was the powerhouse behind such designs as the F-104 Starfighter, U-2, A-12, and SR-71. (Lockheed Martin)

More gloomy news followed in January 1958 when two intelligence assessments of Soviet interception capabilities had been compiled. They indicated that the only areas where the U-2 could fly without certain detection were central Siberia and east of Tashkent to China. Two new types of radar had been detected; in addition, it was considered likely that limited numbers of a specially designed fighter, having the ability to operate above 70,000ft, would soon be available and that SAMs were expected to become a serious threat to Aquatone from 1959 onward. The pressure was now on to rapidly develop and deploy not a stealthy U-2, but a U-2 replacement.

January 1958 saw "the Agency" (CIA) assign the cryptonym Gusto to phase two of Rainbow; and at the end of the month, Johnson wrote to Bissell proposing a four-point work statement for Gusto which was approved on February 11. It was also at about this time that Lockheed built their first anechoic chamber in which to measure the RCS of various design models.

Johnson and some of the key members of his team, including Dick Boehme, Ed Baldwin, and Harry Combs, now began working on a number of high-risk subsonic designs – low RCS being their top priority. They would formulate a shape with minimum RCS values and then work on ways to make it fly within the specified performance envelope. This series of designs were known to the Agency as Gusto Model 2, and over the following months Lockheed studied numerous design permutations under this overarching codename. One rejected design featured cutting notches out of the leading and trailing edge of the wing and inserting triangular wedges of graded dielectric material. This technique, called "softening," avoided generating an abrupt change in resistance of the incoming radar beam when it first met the aircraft (it is these abrupt changes that generate reflections). Utilizing this technique, when the incident beam strikes the baseline of the triangle

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During the missions over North Vietnam, the bogus five-digit red serial number was the only detail applied to the overall black paint scheme.


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(located at the outer edge of the aircraft), it is reflected inside the wedge, generating electrical currents that turn the radio frequency energy into heat. The resistance progressively reduces to zero by the time the energy reaches the tip of the triangular wedge, at which point it matches that of the adjacent metal structure. Invented by Ed Lovick, the technique would play an important role in reducing the RCS of Johnson's ultimate design.

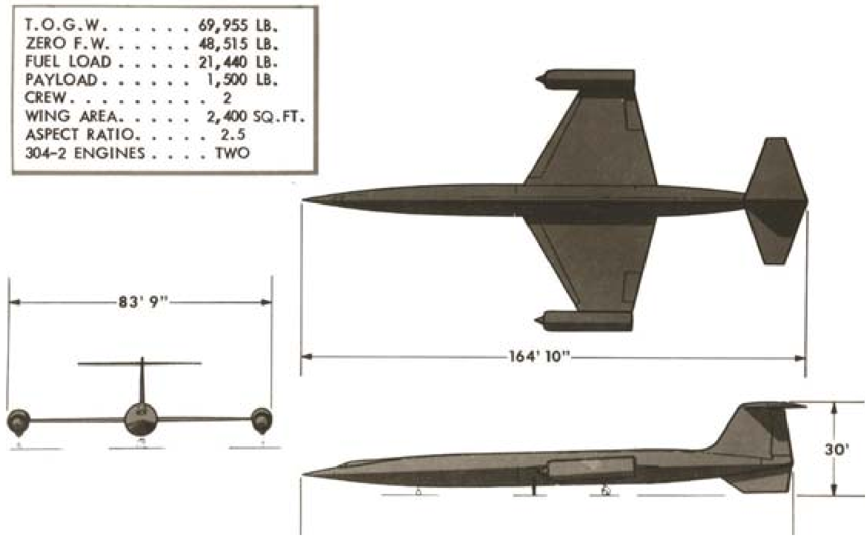
Project Suntan

In the mid-1950s and in parallel with Rainbow and Gusto, Johnson also began looking at a high-altitude, Mach 2.5, non-stealthy replacement for the U-2, funded by the Air Force. Codenamed Project Suntan, it was proposed that the engines, built by Garrett, would be fueled by liquid hydrogen. On February 15, 1956, two Skunk Works design proposals, designated CL-325-1 and CL-325-2 and powered by the supersonic Rex III liquid hydrogen engine, were presented to the Air Force at Wright Field. But after extensive studies the Air Force became convinced that Garrett was incapable of building an engine as complex as that proposed. Consequently, on October 18, 1956, it issued a directive demanding that all work on both projects be stopped. However, as the result of an earlier meeting at the Pentagon with Lt Gen Donald Putt, head of Air Research and Development Command, Kelly offered to build two prototype hydrogen-fueled aircraft powered by more conventional engines and have them delivered within 18 months of contract signing. Based upon the CL-325, they would be capable of cruising at an altitude of over 99,000ft at a speed of Mach 2.5 and have a range of 2,500 miles.

Whilst the Air Force funded studies to verify Kelly's proposal, they also invited both Pratt & Whitney and General Electric to submit proposals to build a hydrogen-fueled engine. On May 1, 1956, two six-month study contracts were signed, one with Pratt & Whitney for the engine and the other with the Skunk Works to evaluate airframe configuration and material options. As a result, contracts were awarded by the Air Force to the Skunk Works to produce four production aircraft and a single static test specimen; the design was designated CL-400-10.

On August 18, 1957, Pratt & Whitney had completed its first Model 304 engine and less than a month later, static tests were initiated. During October initial engine runs took place, followed by a second series in December. A second engine began tests on January 16, 1958 and on June 24 an improved engine, Model 304-2, was delivered and tested.

All seemed to be running according to schedule: the Air Force had allocated $95 million to Project Suntan; Johnson had ordered no less than 2½ miles of aluminum extrusion for airframe production; the 304 engine continued to perform as planned; Air Products was constructing a large hydrogen liquefaction plant in Florida for fuel production, and MIT was working on an inertial guidance system. But over the next six months something continued to bother Johnson. Despite having successfully sold the aircraft to the Air Force, it was becoming increasingly apparent to him that the CL-400's severe range limitations couldn't be designed out of the aircraft. The design fell short of its estimated original lift-over-drag ratio by 16 percent. Stretching the fuselage to increase fuel capacity would result in only a 3 percent increase in range. Pratt & Whitney estimated that no better than a 5–6 percent improvement in specific fuel consumption could be achieved with its Model 304 engine over a five-year period of operation. Such low growth

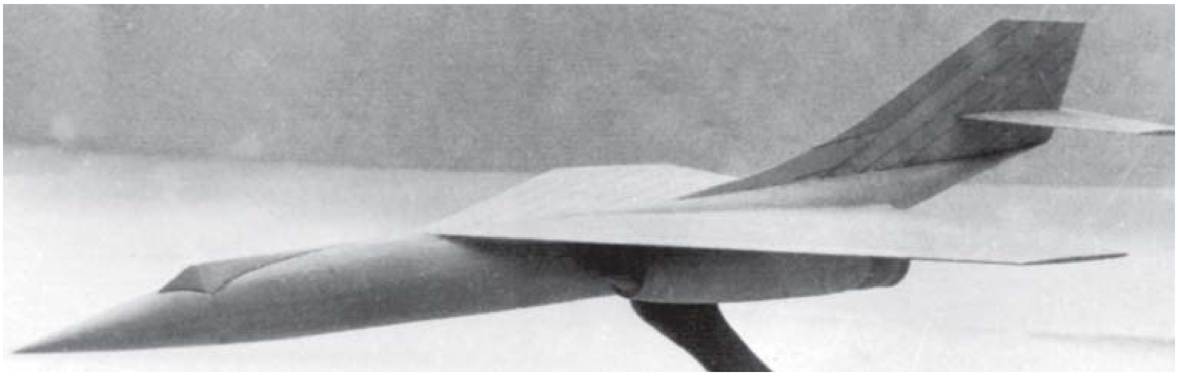


Although not part of Project Rainbow or Gusto, Project Suntan's CL-400 design provided Johnson with important insights into possible fuel and power plant options for a U-2 replacement. (Lockheed Martin)

potential, coupled with the associated logistical problems of pre-positioning liquid hydrogen to OLs, convinced Johnson that "the aircraft was a dog." In March 1957, during a meeting with James Douglas Jr, then Secretary of the Air Force, and Lt Gen Clarence Irvin, deputy Chief of Staff for material, Kelly bluntly informed them of his misgivings and by the middle of that year, others were voicing similar concerns. In February 1958, and at Kelly's insistence, Suntan was canceled. The Skunk Works returned almost $90 million and the Air Force perhaps lost an opportunity to wrestle the strategic reconnaissance overflight program away from the Agency. However, Project Suntan had provided Lockheed with an improved understanding of high-speed flight as well as confirmation that hydrocarbon fuel, and not hydrogen, was the best choice for the proposed flight regime. It also provided Johnson with a major change of direction for Project Gusto.

Supersonic Gusto

The dichotomy was the relationship between "stealth" and performance, and this would be a recurring theme throughout Johnson's design submissions for a U-2 replacement. A conventional design was most likely to deliver the required performance, but these criteria often proved to be too easily detected by radar; whereas a design emphasizing stealth struggled to deliver the prerequisite performance. Johnson was also concerned at the speed of Soviet radar development which, coupled with the inevitable use of more diverse radar frequencies, would, he was convinced, further complicate the search for a panacea to these conflicting paradigms. Therefore on April 21, 1958, probably as a hedge against these problems, Johnson began sketching his first Mach 3 design for the Agency. As with his Suntan design for the Air Force, this primarily put extreme speed and altitude performance at the heart of vehicle "survivability," rather than stealth. He named the design in his notebook "U-3" (this notebook would subsequently become known as his "Archangel" notebook – Skunk Works insiders often referred to the high-flying U-2 as "Kelly's Angel," but as this new design represented another performance leap, "Archangel" seemed the logical extension). He also



Johnson proposed that his Archangel I design be powered by two J58s and built from titanium B 120CVA. Together with Gusto 2A, the designs were received with interest by Dr Richard Bissell, the DCI's Special Assistant for Planning and Coordination, but would come to nothing. (Lockheed Martin)

recorded the basic design requirements and his preference for choosing two higher thrust-to-weight ratio J58 engines over the J93. Then over a number of days, he continued to refine and further investigate the high-speed design, before reporting his findings to Bissell.

A team from the SEI conducted a blip-scan analysis of Johnson's U-3 proposal. By taking into account the design's speed, altitude, and RCS, they were able to evaluate the dwell time (the length of time the aircraft remained within a radar beam) and therefore its probability of detection. Three different frequency bands – 70, 600, and 3,000 megacycles per second – were considered in these computations and the subsequent report was highly significant; becoming known as the "Blip-Scan Study," it set specific performance targets for the U-2 follow-on: a speed of Mach 3, an altitude of 90,000ft, and an RCS of not more than 10m^2 and preferably less than 5m^2.

Convair's competitor

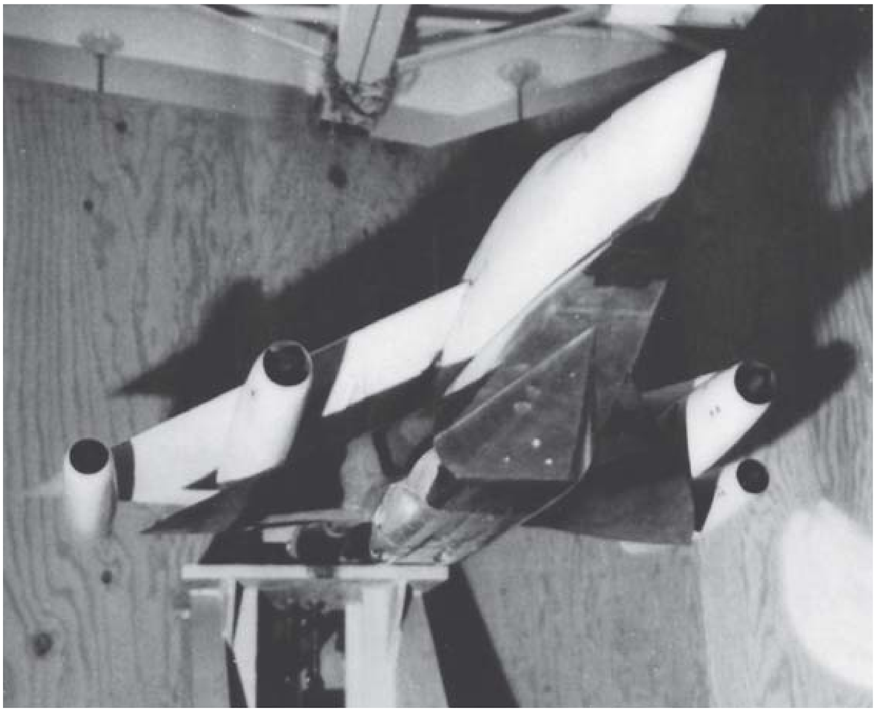
In the spring of 1958, Bissell flew to Fort Worth, Texas, where he met Robert H. Widmer, head of advanced development at the Convair Division of General Dynamics. Bissell told Widmer that he required a reconnaissance aircraft capable of flying undetected at 90,000ft with a 4,000-mile range and 2,000lb payload – as with Lockheed, Bissell kept his initial requirements simple and without a written specification. Bissell states in his memoirs that he brought Convair into the project on a point of due diligence and also to assuage any criticism when it came time to possibly award a multi-million dollar contract. However, others on the inside track have gone on record as saying it was done because Johnson was more concerned about taking an aerodynamic quantum leap, rather than minimizing the RCS of a U-2 successor (the latter being something that President Eisenhower himself had insisted upon). Therefore, this precipitous action also provided Bissell with leverage to use against Johnson when he thought the Skunk Works boss was not focusing enough on RCS design issues.

Convair's first proposal in the competition was based upon a radical variation of a design called Super Hustler. This nuclear bomber would have used a modified B-58 Hustler bomber to carry aloft a two-stage parasite aircraft, the aft section of which would later be jettisoned to increase overall range. The front, manned, section carrying the weapon was to have been powered by ramjets for cruising and a turbojet for landing. It was an interesting concept, but the proposed reconnaissance variant required a number of significant changes, not least because jettisoning sections of an aircraft over hostile territory was hardly covert! In addition, Super Hustler just was not stealthy. So a team of seven principal design engineers, under Donald R. Kirk, began working on what they referred to as the First Invisible Super Hustler or FISH.

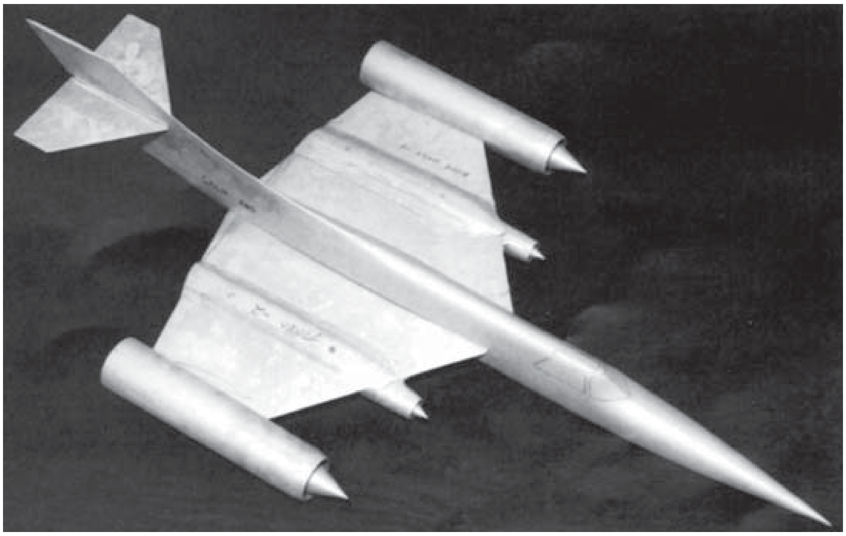
Consisting of the front section only of the Super Hustler design, crew numbers for FISH were reduced from two to one. Its offset, pressurized cockpit escape capsule (a feature that would latter be incorporated into the company's F-111 design) meant that the pilot didn't require a full pressure suit (unlike the Lockheed designs), which greatly reduced crew fatigue. To provide the pilot with a view of the outside world when in flight, two TV cameras were mounted in the nose. Once launched from the B-58, the two ramjet engines would burn high-energy fuel. To reduce FISH's RCS, the designers changed both the leading and trailing edges of the wing from straight lines to arcs of circles, and the inlet was also redesigned. In addition, the steel-honeycomb wings of this Mach 4 hot-rod incorporated the wedge-shaped dielectric inserts invented by Ed Lovick; but due to the high thermodynamic temperatures encountered at such speeds, their composition was changed and instead consisted of a ceramic, Pyroceram, impregnated with graphite. The project was codenamed Idiom by Bissell's office and on June 22, 1958, the work was formally moved into Gusto.

On July 23, 1958, Johnson attended a meeting at which he presented Archangel I and Gusto 2A. Bissell was present and Johnson noted in his log that both designs were "well received." A Navy commander also present alluded to a Navy idea for an inflatable aircraft, and Bissell requested Kelly's comments on the concept. On July 31 the advisory panel met to formally discuss both Lockheed concepts, during which Bissell noted that reasonable progress was being made, but that he thought the way forward would become clearer after their September meeting.

Having been provided with details about the intriguing Navy concept, Johnson conducted a thorough evaluation for Bissell. Under the Navy project



This wind tunnel model shows Convair's FISH concept being carried beneath the underside of its B-58 launch aircraft. (Lockheed Martin)



Powered by two J58s and two wingtip-mounted ramjets, Johnson's Archangel II design precluded provision for reducing RCS, so yet again he was reminded of President Eisenhower's requirement for an "invisible" aircraft. (Lockheed Martin)

name Champion, Goodyear was proposing a reconnaissance vehicle with inflatable wings that could be rolled up whilst in transit aboard an aircraft carrier, then inflated for launch. It was envisaged that the ramjet-powered vehicle would be lifted to altitude by balloon and would cruise at 125,000–150,000ft. A quick calculation by Johnson determined that the balloon would need to be over a mile in diameter! A more detailed study followed during which a tug aircraft was also evaluated, but the unreliability of the concept for reconnaissance over highly sensitive areas was enough to ensure that the design didn't progress.

On August 18, Johnson made a note in his log to conduct studies into a modified version of Archangel I utilizing ramjets on the wingtips to gain a further 10,000ft in altitude. However, Archangel II made no concessions to reducing RCS and during meetings held in Washington, DC and Boston from September 17–24, Johnson was once again reminded that the President required a replacement reconnaissance aircraft that was invisible to radar.

The Land Panel convened in Boston on September 22–23, and both Johnson and Widmer presented their designs independently. The panel decided to terminate further studies into Champion, voiced interest in the Convair design, but rejected Archangel II primarily on the grounds of its poor RCS. Gusto 2A, the panel contended, required further development.

Five days after the Boston meeting, Johnson began making notes on what would become his A-3 design. Consisting of two wingtip-mounted ramjets and two JT-12A turbojets, Johnson assigned the concept to Dan Zuck, Ed Baldwin, and Henry Combs. Continuing the angel theme, the team referred to them as Cherubs, since they were smaller than Archangel, and they worked on several design permutations. On October 30 Ed Baldwin completed the final A-3 design, which had a length of 62.3ft, a span of 33.8ft, and weighed in empty at 12,000lb. Despite the relatively low levels of thrust generated by the two turbojets, the A-3 could reach Mach 3.2 at a cruise altitude of 95,000ft and had a range of 4,000nm. But weight issues dogged the design and when "LD" MacDonald and his team conducted RCS measurements on two scale models, the returns averaged out as the same for those of the U-2, which were much greater than those for the all-metal Gusto 2S, which were themselves larger than for Gusto 2A, which incorporated RAM.

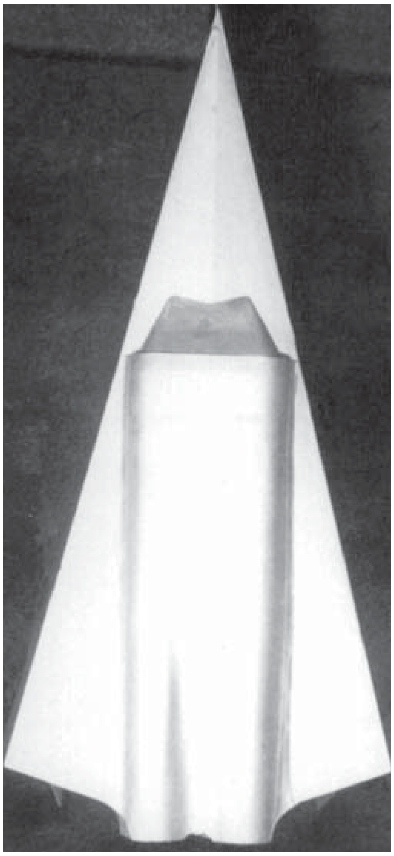
On November 12, 1958, Johnson and Widmer presented their designs to the Land Panel – Johnson the A-3 and Widmer FISH. Three days later the panel communicated its findings to James Killian – the President's science advisor. Their recommendation was that FISH be selected, but should this design later prove unable to meet "the desired technical features" the panel would wish to review other alternatives before recommending firmly a second choice (the A-3).

Bissell called Johnson with the bad news on November 26, pointing out that actually the two designs compared quite favorably, but that the crunch issue had again been RCS, an area in which Convair was clearly ahead.

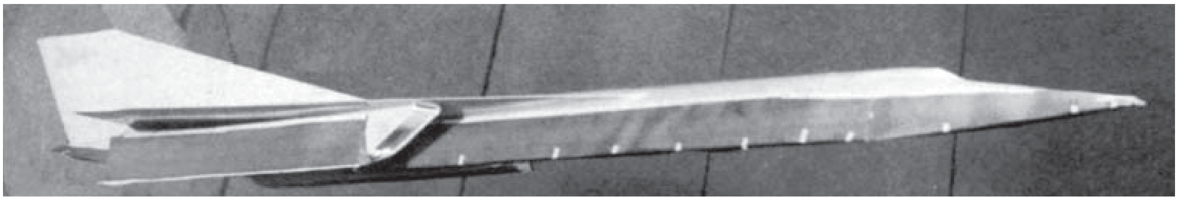
On December 22, Convair was given the go-ahead to proceed with further detailed design development of FISH. Twelve aircraft were to be bought and it was thought that a minimum of one B-58 launch-aircraft would be required for every four FISH. Since Strategic Air Command (SAC) was operating a wing of B-58 Hustler bombers from Carswell AFB in Texas, the base provided ready cover and security for Project FISH – the close proximity of the base to Convair's Fort Worth plant was also an advantage.

A major operational disadvantage of FISH was its reliance upon a carrier aircraft for launch. The effect upon Johnson of the Land Panel's decision to reject the A-3 caused him to focus his next set of designs on reducing RCS values to a minimum, whilst retaining the vehicle's ability to launch itself independently. Therefore, beginning on November 26 and over the next two months, Johnson and his team began working on designs designated A-4, A-5, and A-6. The designs utilized an idea of Frank Rodgers to incorporate chines beginning at or near the nose that blend into the fuselage and merge into the leading edge of the wings. In addition, the designs were of small physical size and vertical surfaces were hidden above the wings. However, at the beginning of January 1959, before design studies had been completed on the A-6, Johnson instructed his team to work on a series of small, non-stealthy designs, designated A-7 through A-9. Powered by a single J58 turbojet and two ramjets, none of the designs were subsequently judged to be viable – their range was inadequate, typically 1,640nm – and despite their size, the RCS was too great.

Following the November 12 meeting, Convair began developing production plans, awarding subcontracts for the design of various sub-systems, in addition to conducting work that would refine and test various elements of their FISH design. But it was during the nearly 300 hours of wind tunnel testing of 1/17th scale models that problems were identified. Firstly the drag coefficient acting on the B-58 with FISH in place was nearly double that of a "clean" aircraft.

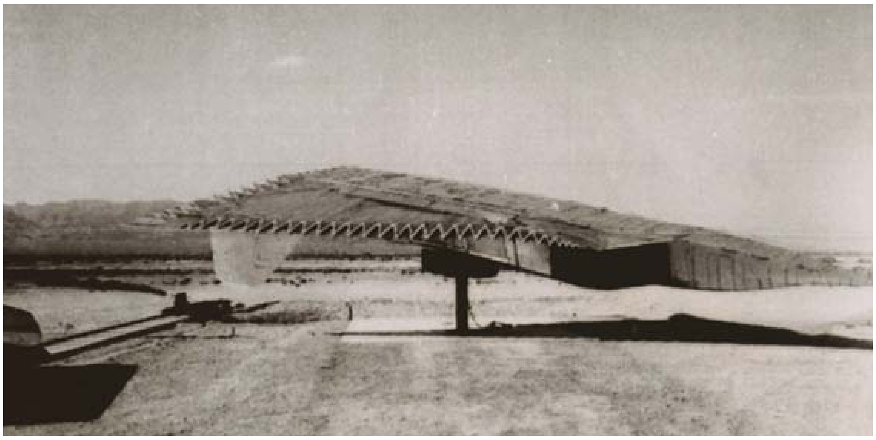


Johnson's Arrow design was the result of a request by the Land Panel to undertake a "sanity check" of Convair's radical FISH proposal. Lockheed highlighted similar operational problems with the design, namely the unreliability of ramjets in cruise and a power deficiency of the proposed single JT-12 turbojet to be used during the landing phase. (Lockheed Martin)



Yet another design with no concessions made to "stealth," the A-10 was built to cruise at Mach 3.2 and 90,500ft. It is seen here undergoing RCS tests to determine how effective the addition of RAM applied to slope the sides of the fuselage and engine nacelles might be. (Lockheed Martin)

KINGFISH, inverted, undergoing RCS testing. Note the serrated leading and trailing edges into which would later be fitted dielectric wedges to further reduce the aircraft's RCS. The intakes located above the wing would also contribute to lowering the design's radar return. (Lockheed Martin)



This meant that instead of the usual three minutes to accelerate from subsonic speed to Mach 2, it would take nearly nine. In addition, FISH needed to be lengthened in order to improve stability and carry additional fuel; this meant that the B-58 needed to be 5ft longer. Neither of these were issues for the B-58B, as it was both longer and had uprated J79-9 engines; the problem was that the new bomber was unfunded.

Following the failure of both his small stealthy and non-stealthy designs, Johnson returned to his Archangel I concept of a purely performance-driven design with no concessions to reducing RCS. The A-10 and A-11 designs were the results of pursuing that philosophy.

Utilizing the J93 turbojet, the A-10 was 16,000lb lighter than Archangel I and was therefore able to gain an additional 2,500ft at mid-mission altitude. It was able to cruise at Mach 3.2 at 90,500ft and had an operational radius of 2,000nm. However, it transpired that the J93 engines were 18 months behind the development of the J58; so in March 1959 the Lockheed team began work on what they believed would be their final major design, the A-11. Designed specifically to utilize air refueling, it would therefore have a range of over 13,000 miles and be able to complete an eight-hour round-robin mission from the United States, thus negating the inherent political and security issues associated with operating such aircraft from a foreign base.

By the end of May 1959 the SEI team at Cambridge had completed a comparison evaluation between the A-11 and FISH and their report, recommending the A-11, was forwarded to the Land Committee, who again met independently the two competing teams in Boston on 9 June. The Committee adjourned without making a definitive decision; however they did conclude that sporadic detection and tracking by radar was inevitable regardless of the platform. On the flight back to Burbank, Johnson was convinced that Lockheed was now out of the competition.

In the event, it wasn't the Land Committee that decided the fate of the two designs that they had been deliberating over, but SAC. In an interesting turn of events, Widmer accompanied his corporate boss, J. T. McNarney, and other senior Convair directors to a presentation in June that included Gen Curtis LeMay, Vice Chief of Staff of the Air Force. Convair's objective was to sell the capabilities of the B-58B to the Air Force. However, to make the earlier B-58A commercially viable, the company needed first to sell more A-models. The presentation seems to have gone well; LeMay liked what he saw and asked, "When can I have this?" Unfortunately for Convair, he didn't like the answer;

and when McNarney told the notoriously fiery general that the B-58B would be available after SAC had purchased another three wings of B-58As, LeMay stormed out. Consequently the B-58B was never ordered by the Air Force and without its mother ship, the parasite FISH would not be built either.

The final competition

In early July, and much to Johnson's surprise, Lockheed was instructed to redesign the A-11 incorporating RCS reduction techniques, even to the detriment of cruise altitude. In contrast, Convair was instructed to undertake a colossal amount of work completely redesigning FISH as a single-stage platform, not reliant upon a mother ship and utilizing two J58 turbojets instead of ramjets. They called their new design KINGFISH.

The Convair team now pulled out all the stops, working through three or four design variations. Remarkably, in just over two weeks they had not only decided upon the basic design, but had also considerably modified the FISH radar model being used for RCS testing at Indian Springs AFB in Nevada, to the larger KINGFISH configuration. The KINGFISH model then undertook a series of 70 MHz radar tests from August 15 – the results of which would turn out to be similar to those achieved by the A-12.

The addition of fuselage chines to the "Blackbird" family's circular forebody transformed its cross-section into a "stealthy" two-dimensional "flying saucer," a discovery made independently by both Frank Rodgers and Ed Lovick. (Paul F. Crickmore)

This rare color shot shows engineers within Skunk Works Building 309/310 at Plant B-6, getting ready to position the inboard wing leading-edge serrations onto an A-12. (Lockheed Martin)

"LD" MacDonald and Ed Lovick advised Dick Fuller how best to modify the A-11 design into the reduced RCS A-12. This included using chines, suggested by Frank Rodgers during the A-4 series of designs. Once these were applied a cross-section of the fuselage forebody resembled a two-dimensional flying saucer! The wings were blended into both the fuselage and engine nacelles, whilst the twin tails were made of composite material and also canted inboard at 15 degrees. Other more subtle RCS reduction innovations included incorporating Ed Lovick's serrations that were applied to the wing leading and trailing edges as well as to the chines, which were then filled with dielectric material, as explained earlier. The A-11's rectangular inlets were replaced with round, axisymmetric units; and the two translating spikes, used to regulate mass airflow into each inlet, not only helped to shield the front of the compressor face from incident radar energy, but also were covered in RAM.

On July 14, Bissell and the Land Committee together with James Killian met and discussed the pros and cons of FISH, KINGFISH, the A-11, and A-12, in addition to reports speculating about the possible capabilities of the new Soviet Bar Lock radar. Like the June 9 meeting, a final decision regarding which design to recommend wasn't made; however, those present did begin to formulate a briefing to be taken by Dulles and others to President Eisenhower six days later.

Final proposals from both Convair and Lockheed were submitted on August 20 and nine days later Lockheed received official notification that their design had been selected by the Committee, and that consequently the company would receive $4.5 million by way of an advanced feasibility contract, covering the period September 1, 1959 to January 1, 1960. The name of the new program was to be Oxcart and Project Gusto was to be terminated. On August 31, 1959, Lockheed began building a full-scale RCS model with which to validate their RCS claims. However it was decided that the site at Indian Springs AFB couldn't provide the required level of security to test a full-size A-12 model, so Johnson instructed that these tests would instead be conducted at the radar target scatter (or Rat Scat) range, located at Area 51.

Area 51, or "Watertown Strip" as it had been known to the U-2 community, offered exceptional remoteness. Located about 100 miles northwest of Las Vegas, the site would also be home for Oxcart. However, a vast amount of work was necessary both at the airfield and the Rat Scat facility to bring them up to the standards required for this new advanced program.

In December 1959, John Parangosky was appointed as the CIA's program manager of Oxcart. Following validation of the A-12's RCS tests, a contract worth $96.6 million was signed between the Agency and Lockheed on February 11, 1960, for the manufacture and testing of 12 A-12s, including one two-seat conversion trainer. The CIA had included a clause within the contract providing for periodic re-evaluation of costs – a clause that had to be invoked a number of times in the coming five years due to spiraling costs attributed to technical difficulties.

Mayday

Despite misgivings, Eisenhower continued to sanction a limited number of U-2 Soviet overflights on the basis of the continuing need to collect such intelligence and the ongoing failure of the Corona satellite reconnaissance program to plug the gap. But on May 1, 1960, Soviet radar and SAM technology finally caught up with Project Chalice, when the U-2 being flown by Gary Powers was shot down near Sverdlovsk, deep within the Soviet Union. Two days later, assuming that Powers had been killed, approval was given by Eisenhower to put out a prearranged cover story in which NASA claimed that one of their U-2 research aircraft "apparently went down" after the pilot "reported that he was experiencing oxygen difficulties." This played perfectly into Premier Khrushchev's hands and on Saturday, May 7, having returned to the Supreme Soviet, he revealed to the world the truth: "We have the remnants of the plane – and we also have the pilot, who is quite alive and kicking!" The wreckage, maps and even film were recovered proving, beyond dispute, the precise reason behind the flight. A subsequent mid-May summit meeting in Paris was a disaster, during which Khrushchev walked out after Eisenhower refused to apologise publicly for sanctioning the U-2 overflights (despite having assured the Soviet Premier that there would be no more such flights during the remaining eight months of his administration).

A serious question thus arose regarding the future status of Oxcart. On the one hand, it vindicated the decision to develop a U-2 replacement; but it also opened up a debate as to whether the United States should continue violating Soviet airspace with its manned strategic reconnaissance program.

In late May, Eisenhower told his military aide Brig Gen Andrew Goodpaster that he believed the project should go forward on low priority, for Air Force use in time of war. In a subsequent memo for the record, Goodpaster noted that Eisenhower "Did not think the project should be pushed at top priority. In fact, they might come to the conclusion that

A 1/8th scale A-12 model undertakes RCS testing. The extensions aft of the engine nacelles were added to simulate the aircraft's exhaust plume. (Lockheed Martin)

it would be best to get out of it if we could." But with Corona still struggling, there was no viable option to Oxcart available in the short-to-mid-term, so the program survived.

Whilst production work on the A-12 got underway at the Skunk Works plant in Burbank, California, so too did construction on a 12,000ft runway extension, workshops, hangars, and a raft of other support facilities out at Area 51. The operational unit for Oxcart was designated the 1129th Special Activities Squadron (SAS), and the selection process for its pilots was evolved in 1961 by Brig Gen Flickinger, Col Houser Wilson at the Pentagon, and the Director of the Agency's Office of Special Activities (OSA), Brig Gen Jack Ledford (later succeeded by Brig Gen Paul Baclais), who together defined the required physical and experience criteria. Pilots were required to be qualified in the latest high-performance aircraft, highly proficient in air refueling, emotionally stable, married, and especially well motivated. In addition, candidates had to be between 25 and 40 years of age, weigh less than 175lb, and be under 6ft tall. There followed a week of psychological assessments in various hotel rooms in Washington, DC and then an extensive medical examination at the Lovelace Clinic at Albuquerque, New Mexico. Once the process was completed, the 11 successful candidates began taking trips to the David Clark Company in Worcester, Massachusetts, to be outfitted with their personal S-901 full pressure suits.

Following further production delays in Burbank, the May 1961 planned delivery of aircraft number one to the Area 51 test site proved overly optimistic and slipped to late summer. Problems in procuring and working with titanium, combined with difficulties experienced by Pratt & Whitney, prompted Johnson to write to CIA officials explaining that schedules could slip from between three to four months. The response from Bissell was predictably curt, his memo finishing with, "I trust that this is the last of such disappointments short of a severe earthquake in Burbank."

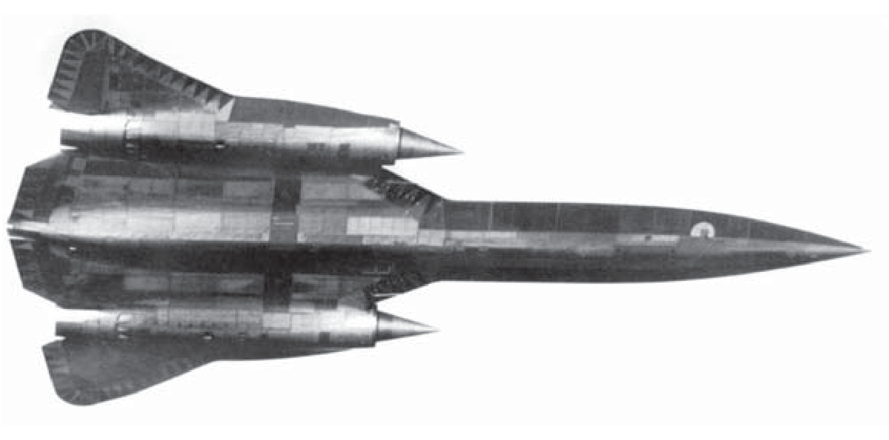
Despite the production problems, Oxcart preparations continued in various parts of the world, with high-capacity fuel tank farms constructed at Air Force bases in California, Alaska, Greenland, Okinawa, and Turkey, to provide worldwide storage of the A-12's special fuel in readiness for the jet's operational sorties. Additional fuel storage facilities were also prepared at bases in Arkansas and Florida to support transcontinental training flights. The 903rd Air Refueling Squadron based at Beale AFB, California, was designated to support Oxcart air refueling operations and was equipped with special KC-135Q tankers, which possessed separate "clean" tankage and plumbing to isolate the A-12's fuel from the tanker's own JP-4. These tankers were also equipped with special ARC-50 distance-ranging radios to facilitate discrete, precision, long-distance, high-speed join-ups.

The first A-12, Article 121 (60-6924), being removed from its crate at Area 51, having arrived by road. (Roadrunners Internationale)

During January and February 1962, final checks were at last successfully conducted on aircraft number one (Article Number 121; USAF serial number 60-6924). The airframe was then dismantled, loaded onto a custom-built trailer and on February 26, 1962, transported to Area 51. Following reassembly at its new desert home and whilst being prepared for the first flight, yet another delay occurred when the aircraft began leaking fuel profusely from its "wet" tanks. An investigation revealed that the specially designed sealant had failed to adhere to surfaces between the fuel tanks and the metal skin of the aircraft. The defective sealant was removed and the tanks relined – but tank sealant issues on all variants of the aircraft remained an issue throughout its life.

Having successfully completed a series of low- and medium-speed taxi tests, Lockheed Chief Project pilot, Lou Schalk, was scheduled to take Article 121 on a high-speed test on April 24, 1962. The test-card called for the evaluation to culminate in a momentary lift-off and landing roll-out onto the dry salty lakebed. For this first "hop" the A-12's stability augmentation system (SAS) was left uncoupled – it was planned to test this properly in flight. However, as Lou Schalk recalls, immediately after lift-off everything went badly wrong:

> I really didn't think I was going to be able to put the aircraft back on the ground safely because of lateral, directional and longitudinal oscillations. The aircraft was very difficult to handle but I finally caught up with everything that was happening, got control back enough to set it back down, and chop engine power. Touchdown was on the lakebed instead of the runway, creating a tremendous cloud of dust into which I disappeared entirely. The tower controllers were calling me to find out what was happening and I was



Photographed during a test flight on December 22, 1962, Article 123 (60-6926) was the third A-12 to be built. The innovative "blended body" design merging both the fuselage and engine nacelles into the wings to reduce RCS is clearly depicted. (Lockheed Martin)

A-12 chief test pilot Lou Schalk (center, in flight suit) is congratulated by "Agency" and Lockheed officials following successful completion of the A-12's first "official" flight on April 30, 1962. Note the F-104 Starfighter chase plane in the background. (Lockheed Martin)

answering, but the UHF antenna was located on the underside of the aircraft [for best transmission in flight] and no one could hear me. Finally, when I slowed down and started my turn on the lake-bed and re-emerged from the dust cloud, everyone breathed a sigh of relief.

Two days later, Schalk successfully completed a trouble-free first real test flight lasting 35 minutes – for which the SAS dampers remained switched on!

Over the next few months Article 121 was joined by more of its stablemates. Article 122 (60-6925) arrived on June 26, but was destined to spend three months conducting ground radar tests before taking to the air. Aircraft number three (Article 123; 60-6926) arrived in August and flew in October. In November the two-seat pilot trainer (Article 124; 60-6927) was delivered, which was planned to help smooth transition training. The aircraft was to have been powered by J58 engines, but as engine production problems persisted, it was decided to equip the two-seater with J75 engines and let the checked-out pilots go on to high-Mach flight on their own. Therefore the AT-12 trainer aircraft, nicknamed the "Titanium Goose," undertook its maiden flight in January 1963 fitted with the less-powerful engines. Aircraft number five (Article 125; 60-6928) was delivered to the site on December 19, 1962.

The Cuban Missile Crisis once again demonstrated the U-2's vulnerability to SA-2 attack in spectacular fashion when Air Force Maj Rudy Anderson was shot down and tragically killed during a reconnaissance mission over the Caribbean island on October 27, 1962. But still there was no sign of Oxcart entering service.

On January 15, 1963, the first flight of an A-12 powered by two J58s finally occurred and by the end of the month ten engines were available and the test program began to gain momentum. The biggest hurdle facing both test pilots and engineers was perfecting the air induction system, designed to vastly augment engine thrust. To achieve Johnson's design goal of sustained Mach 3.2 flight, the air inlet spike's aft-movement, together with the precise position of various bypass doors, had to initially be manually programed extremely accurately by the test team to ensure that the terminal shock wave was

B

1. A-12

Serial 60-6933, this aircraft was the tenth A-12 built.

2. AT-12,

The two-seat A-12 pilot trainer.

3. YF-12A,

Serial 60-6935, as it appeared when operating with NASA, configured with instruments for a series of "cold-wall" experiments.

4. SR-71A

The A-12's replacement as the United States' Mach 3 reconnaisance aircraft. The two-seat SR-71 had a radar antenna in the nose, equipment bays in the underside of its chine, a longer "boat-tail," and a circular "window" in the upper fuselage for its astroinertial navigation system.

1


06933
U.S. AIR FORCE

2


06935
NASA
935
U.S. AIR FORCE

3


06933
U.S. AIR FORCE

4


17979
979
U.S. AIR FORCE

Article 123 was the first of five A-12s lost in accidents. The aircraft crashed on May 24, 1963, whilst being flown by Ken Collins during a subsonic flight test – the airframe had accumulated just 135.3 flight hours. (Lockheed Martin via Tony Landis)

positioned in exactly the correct position in order to stabilize airflow in the inlet duct for future flights. When these parameters were finally achieved, the A-12's thirst for fuel – particularly during the transonic phase of acceleration – was notably reduced. In all, it took 66 flights to extend Oxcart's speed envelope out from Mach 2.0 to Mach 3.2.

But success came at a price. On May 24, 1963, Ken Collins was forced to eject from Article 123 during a subsonic engine test sortie, following an aircraft pitch-up and subsequent loss of control. The cause was found to be ice encrustation in the pitot static system, leading to the display of erroneous flight data. Article 133 (60-6939) was lost on July 9, 1964, just as Lockheed Test Pilot Bill Park was turning onto final approach into Area 51 having just completed a tri-sonic test flight. The aircraft experienced a complete flight control lock-up and Park was forced to eject at about 200kts as the aircraft continued to increase bank-angle at just 200ft above the desert floor. The cause was loss of hydraulic fluid to the flight control system.

The four hangars and workshops in the foreground were just part of the major redevelopment necessary to support Oxcart flight operations up at Area 51. To enable the A-12 to be tested both at speed and in a secure environment when airborne, the Yuletide Special Rules Area was established above the base; it extended up from 24,000ft to 60,000ft and was approximately the size of England! (Roadrunners Internationale)

On December 28, 1964, Agency pilot Mele Vojvodich taxied out in Article 126 (60-6929) for a Functional Check Flight (FCF), after the aircraft had undergone deep maintenance. With both burners lit and immediately upon rotating the aircraft, it yawed viciously to one side; corrective rudder application caused 126 to pitch-up. It became apparent that all pilot control inputs were having a reverse effect to those intended – in the midst of these uncontrollable divergent effects, Vojvodich was forced to eject from the aircraft not even 100ft above the ground. With just one swing on the open parachute, Vojvodich narrowly missed the flaming pyre of 126, which signified the end of yet another aircraft. The sortie had lasted just six seconds – the shortest of any "Blackbird" flight. A subsequent inquiry established that the SAS had been wired back into the aircraft incorrectly.

On November 20, 1965, the final stage of the validation process was completed when a maximum-endurance flight of six hours and 20 minutes was achieved, during which time an Oxcart demonstrated sustained speeds above Mach 3.2 at altitudes approaching 90,000ft. But the question remained – where to deploy the bird?

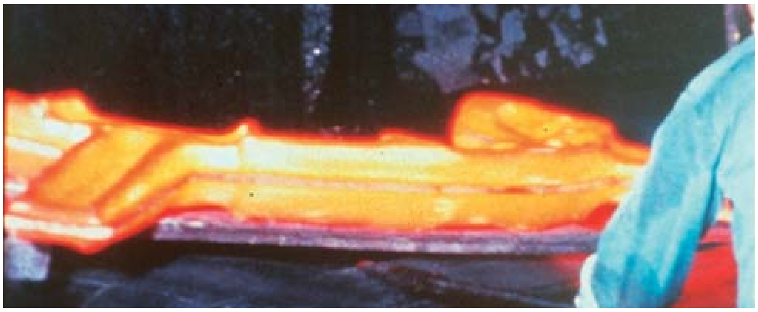
TECHNICAL SPECIFICATIONS

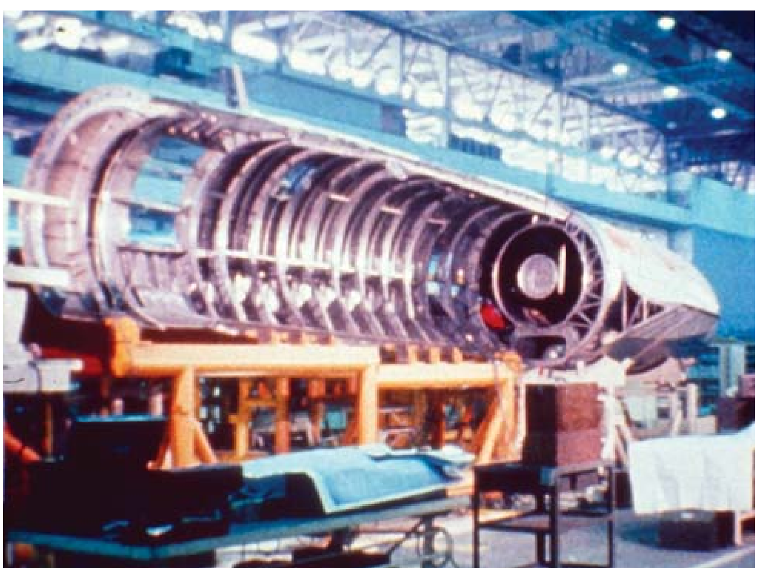
A thermal thicket

The innovative use of shape and materials to produce as stealthy a vehicle as possible was equaled by the necessary use of exotic materials and manufacturing techniques. The best frontline fighter aircraft of the day were the early Century-series jets, like the North American F-100 Super Sabre and McDonnell F-101 Voodoo. In a single bound, the A-12 would operate at sustained speeds and altitudes treble and double respectively those of such contemporary fighters. The technical challenge facing the Skunk Works team was vast and the contracted timescale in which to solve them was incredibly tight. Johnson would later remark that virtually everything on the aircraft had to be invented from scratch.

Operating above 80,000ft, the ambient air temperature was often below –60 degrees C and the atmospheric air pressure just 0.4 pounds per square inch; but cruising in afterburner at a speed of a mile every two seconds, airframe temperatures soared from between 245 and 565 degrees C. However, during the subsonic air refueling phase of a mission, the airframe would be subjected to steady-state temperatures of –65 degrees C. Thermodynamic considerations therefore were fundamental.

Sustained operation in such an extreme temperature environment meant lavish use of advanced titanium alloys, which accounted for 85 percent of the aircraft's structural weight; the remaining 15 percent was comprised of composite materials. The decision to use such materials was based upon titanium's ability to withstand high operating temperatures; it also weighs half as much as stainless steel but has the same tensile strength – high-strength composites were not available in the early 1960s. The particular titanium used was Beta-120/Ti-13V-11Cr-3A1, which can be hardened to strengths of up to 200 Ksi. But using this advanced material wasn't without problems – titanium is not compatible with chlorine, fluorine or cadmium. For example, a line drawn on sheet titanium with a Pentel pen will eat a hole through it in about 12 hours – so all Pentel pens were recalled from the shop floor. Early spot-





welded panels produced during the summer had a habit of failing, while those built in the winter lasted indefinitely. Diligent detective work discovered that to prevent the formation of algae in the summer, the Burbank water supply was heavily chlorinated. Subsequently, the Skunk Works washed all titanium parts in distilled water. As thermodynamic tests got underway, bolt heads began dropping from installations; this, it was discovered, was caused by tiny cadmium deposits, left after cadmium-plated spanners had been used to apply torque. As the bolts were heated to temperatures in excess of 320 degrees C, their heads simply dropped off. The remedy: all cadmium-plated tools were removed from toolboxes.

One test undertaken studied thermal effects on sheets of large titanium wing panels. When a 4ft×6ft element was heated to the computed heat flux expected in flight, it resulted in the sample warping into a totally unacceptable shape. This problem was resolved by manufacturing chordwise corrugations into the wing outer skins. At the design heat rate, the corrugations merely deepened by a few thousandths of an inch and on cooling returned to their original shape. Johnson recalled he was accused of "...trying to make a 1932 Ford Tri-motor go Mach 3," but added that "...the concept worked fine." To prevent this thin titanium outer skin from tearing due to differential expansion rates when secured to heavier sub-structures, the Skunk Works developed stand-off clips; these provided structural continuity while creating a heat shield between the adjacent components.

General layout

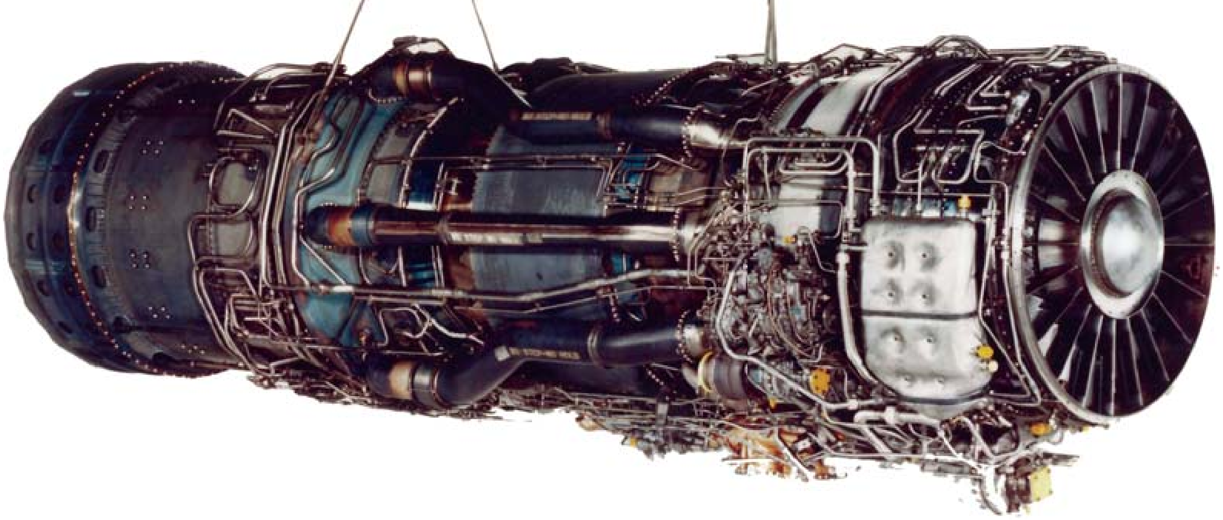
The exterior of the A-12 is characterized by an aft-body delta wing with two large engine nacelles, each mounted at mid-semi-span. Two "all-moving" vertical fins were located on top of each nacelle and canted inboard 15 degrees from the vertical to reduce the aircraft's radar signature. A large, aft-moving inlet spike or center-body protruded forward from each engine nacelle, which helped to regulate mass airflow to the two Pratt & Whitney J58 engines. The fuselage was a titanium structure of semi-monocoque construction with a circular cross-section. The fuselage sides then flared out creating sharply blended chines (the resultant cross-section resembling a two-dimensional flying saucer) which reduced radar returns when illuminated by radar from the side. The fore and aft fuselage bodies were joined during construction at fuselage station (FS) 715. To further reduce its RCS, the A-12's wing leading and trailing edges together with the chines were fitted with wedges of RAM, as described earlier. The primary reconnaissance-gathering system on the A-12 was a high-resolution camera which was located in a large pressurized compartment behind the pilot, referred to as the Q Bay.

OPPOSITE
This sequence of three images was taken from a once-lost cine tape. The first shows a solid titanium ingot being pressed into an engine nacelle ring. The nacelle was an integral part of the wing, acting as a chordwise beam and torque tube, transmitting aerodynamic loads from the outer wing section forwards and redistributing them to the forward and aft wing boxes. The inboard wing sections were in forward and aft box sections, separated by a 3ft 3in-wide compartment that provided support for the main undercarriage. Finally the inboard section of the right engine nacelle is depicted – the rear of the intake spike mount is already in position. (Lockheed Martin)

Engines

The specified power plant for the A-12 was two Pratt & Whitney JT11D20 A engines (designated J58 by the US military). Known as JJ engines, each developed 32,500lb of thrust (as both the YF-12 and SR-71 designs were heavier than the A-12, their modified YJ engines produced 34,000lb of thrust).

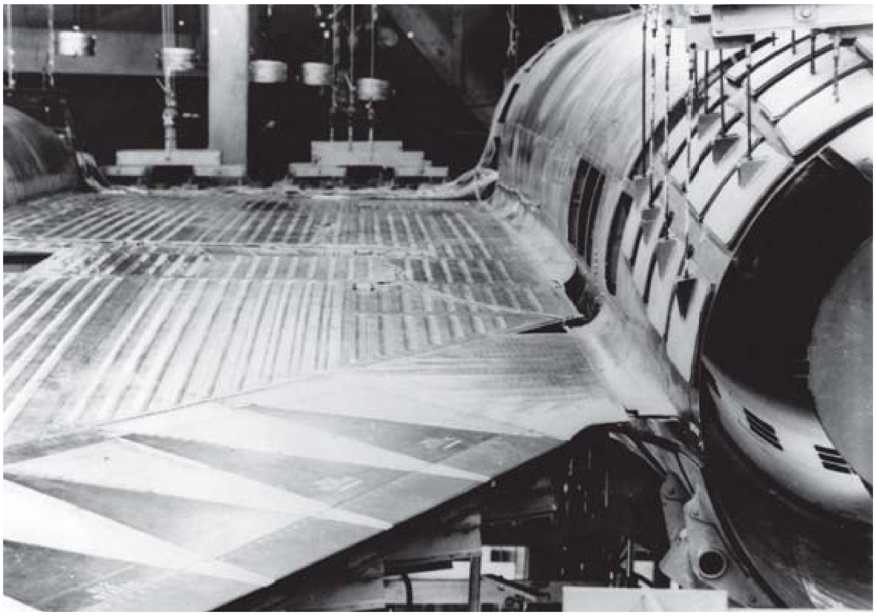
Article 133 (60-6939) was the final A-12 off the line. Note how both outboard wing sections hinge upward to allow installation of and access to the J58 engines; and the Q Bay behind the cockpit that provided the pressurized compartment within which the camera was installed. (Lockheed Martin)



The Pratt & Whitney J58 continued to be developed throughout its life, eventually generating 34,000lb of sustained thrust whilst cruising in afterburner. Three of the six unique compressor bypass tubes can clearly be seen. (Pratt & Whitney)

This high bypass ratio afterburning engine was the result of two earlier, ill-fated programs: Project Suntan together with Pratt & Whitney's JT9 engine that lost out to General Electric's J93 to power the North American XB-70 Valkyrie. So Pratt & Whitney then reduced the engine's size by 20 percent and offered it under the J58 designator for the Vought F8U-3, which in turn lost out in competition against McDonnell's F4H-1.

Although relatively conventional, the original single-spool high pressure ratio turbojet was rated at 26,000lb in afterburner and had already completed 700 hours of full-scale engine testing, with results being very encouraging. As testing continued, however, it became apparent that due to the incredibly hostile thermal conditions of sustained Mach 3.2 flight, only the basic airflow size (400lb per second of airflow) and the compressor and turbine aerodynamics of the original Navy J58 P2 engine could be retained (and even these were later modified). The stretched design criteria, associated with high Mach number and its related large airflow turn-down ratio, led to the development of a variable cycle (later known as a bleed bypass) engine; a concept conceived by Pratt & Whitney's Robert Abernathy. This eliminated many airflow problems through



Undergoing stress testing, note the wedges of dielectric material installed into the serrated wing leading edge to reduce the aircraft's RCS. Note also the chordwise corrugations pressed into the inboard section of the wing to minimize the effects of thermodynamic expansion. (Lockheed Martin)

The successful execution of Oxcart's mission depended upon the air refueling support supplied by specially modified USAF KC-135Q tankers flown by the 903rd Air Refueling Squadron, based at Beale AFB, California. (Lockheed Martin)

the engine by bleeding air from the fourth stage of the nine-stage, single-spool axial-flow 8.8:1 pressure ratio compressor and channeling this excess air through six low compression ratio bypass ducts. It was then reintroduced into the turbine exhaust, near the front of the afterburner, at the same static pressure as the main flow; this reduced exhaust gas temperature (EGT) and produced almost as much thrust per pound of air as the main flow, which had passed through the rear compressor, the burner section, and the turbine. Scheduling of the bypass bleed was achieved by the main fuel control as a function of compressor inlet temperature (CIT) and engine rpm. Bleed air injection occurred at a CIT of between 85 and 115 degrees C (approximately Mach 1.9).

Hydraulics

Four independent systems (designated A, B, L, and R) supplied hydraulic power to the A-12, thereby facilitating operation of the control actuators, landing gear, and other equipment. The A and B systems operated in parallel, supplying hydraulic pressure to the flight controls, specifically the seven actuating cylinders on each outboard elevon, the three on each inboard elevon, and the two cylinders operating each rudder. A dual servo unit, one for each movable flight control surface, controlled system pressure and return of fluid to the actuating cylinders.

The L and R systems supplied hydraulic power to the left and right inlet spikes and the forward and aft bypass doors on each nacelle. The L system also served the normal brake system, landing gear, main gear inboard doors, nose wheel steering system, refueling door and fuel probe receptacle latches. The R system supplied hydraulic power to the alternate braking system, alternate nose wheel steering system, landing gear retraction system, and backup system for closing the main landing gear inboard doors. Each system was serviced by its own hydraulic reservoir and fixed-angle, variable-volume piston pump. The left engine drove the A and L system pumps, while the B and R pumps were driven by the right engine.

Fuel system

The extremely high airframe temperatures encountered by the A-12 during high-Mach cruise ruled out the use of JP-4 as its fuel source, as it had to be carried in "wet" tanks. Instead, a bespoke fuel was designed specifically for the A-12 and known as PF-1 (later known as JP-7). It was developed by Pratt & Whitney, in partnership with Ashland, Shell, and Monsanto, and remained stable despite the high temperature environment, being used first as a hydraulic fluid to activate the main and afterburner fuel nozzles before being injected into the fuel burners at over 350 degrees C and 130 psi. Such high fuel-burn temperatures presented the design team with yet another problem, because standard electrical plugs couldn't ignite the fuel. This was overcome by developing a unique chemical ignition system involving the chemical triethylborane (TEB). Extremely flash sensitive when oxidized, a small tank of the substance was carried onboard the aircraft and used to start or restart the engines and afterburners on the ground or in the air. To ensure that the system remained inert when not in operation, gaseous nitrogen was used to pressurize the TEB tank and power the piston that injected it into the burner cans during the ignition process, regardless of engine operating conditions. As fuel was burnt, gaseous nitrogen was also used to pressurize and render inert the fuel tanks to prevent them from being crushed as the aircraft descended to lower levels to either air refuel or land.

Development of a durable fuel tank sealant was an ongoing problem. Cruising at high Mach the airframe expanded due to thermodynamic heating. Upon descending to air refuel, the airframe cooled – a process that was considerably speeded-up when cold fuel was pumped into the tanks from the KC-135Q tanker at 5,000lb per minute! The pounding taken by the silicon-based sealant invariably led to it cracking, causing fuel to leak from numerous gaps.

Air Inlet Control System (AICS)

The A-12 also boasted a unique, highly efficient air inlet system that supplemented thrust via three components: an asymmetric mixed-compression, variable-geometry inlet; the J58 engine; and a convergent-divergent blow-in-door ejector nozzle. The AICS regulated the massively varying internal airflow throughout the aircraft's entire flight envelope, ensuring that the engines received air at both the correct velocity and pressure.

To satisfy the J58's voluminous appetite for air during operations at ground idle, taxiing, and take-off, the center-body spikes were positioned fully forward, allowing an uninterrupted flow to the engine compressor. Supplementary flow was also provided through six forward bypass doors; additionally, a reverse flow was set up through exit louvers on the spike's center-body and a set of variable-area "inlet-ports" that were regulated by an external slotted-band, which drew air in from two sets of doors. The task of operating these doors and positioning of the electrically operated, hydraulically actuated spike was controlled by the pilot. Operating together, the forward bypass doors and the center-body spike were used to control the position of the normal shock wave, just aft of the inlet throat. To optimize inlet efficiencies, the shock wave was captured and held inside the converging-diverging nozzle, just behind the narrowest part of the "throat," thereby achieving the maximum possible pressure rise across the normal shock.

Once airborne, the forward bypass doors closed automatically as the undercarriage retracted. At Mach 1.4, the doors began to modulate, again automatically in order to obtain a pre-programed ratio between "dynamic" pressure at the inlet cowl on one side of the "throat" and "static" duct pressure on the other side. Upon reaching 30,000ft, the inlet spike unlocked and at Mach 1.6 began a rearward translation, achieving its fully aft position of 26 inches at Mach 3.2 – the inlet's most efficient speed. As the spike moved aft, the "capture-air-stream-tube-area" increased by 112 percent, while the "throat" restriction decreased by 46 percent of its former size. A peripheral "shock trap" bleed slot (positioned around the outer circumference of the duct, just forward of the "throat" set at two boundary-layer displacement thicknesses) "shaved" off 7 percent of the stagnant inlet airflow and stabilized the terminal (normal) shock. It was then rammed across the bypass plenum through 32 shock trap tubes spaced at regular intervals around the circumference of the shock trap. As this air was compressed, tertiary air traveled down the secondary bypass passage, firmly closed the suck-in doors, and cooled the exterior of the engine casing before being exhausted through the ejector nozzle.

Potentially turbulent boundary layer air was removed from the surface of the center-body spike at the point of its maximum diameter and then ducted through the spike's hollow support struts, before being dumped overboard through nacelle exit louvers. The aft bypass doors were opened at mid-Mach to minimize the aerodynamic drag that resulted from dumping air overboard through the forward bypass doors. By carefully dovetailing all the above parameters, the inlet was able to generate internal duct pressures of 18lb per square inch; when this is considered against the ambient air pressure at 82,000ft of just 0.4lb per square inch, it is immediately apparent that this extremely large pressure gradient is capable of producing a similarly large forward thrust vector. In fact, at Mach cruise this accounted for no less than 54 percent of the total thrust being produced; a further 29 percent was produced by the ejector, while the remaining 17 percent was generated by the J58 engine. If, however, airflow disturbances disrupted this delicate pressure-balancing trick, it is equally easy to appreciate the effects that such excursions would have upon the aircraft.

This brings us to yet another of the A-12's unique idiosyncrasies: the "unstart." These unstarts, or aerodynamic disruptions (ADs), occurred when the normal shock wave was "belched" forward from the inlet throat, causing an instant drop in the inlet pressure and thrust. With each engine positioned at mid-semi-span, the shock wave departure manifested itself in a vicious yaw in the direction of the "unstarted" engine; sometimes these were so strong that crewmembers would have their helmets knocked against the cockpit canopy framing. Recovery from such an incident required the pilot to re-sequence the inlet in order to get it restarted. This involved the spike being driven forward and opening the forward bypass doors to recapture and reposition the shock wave. The spike was then returned to its correct position, followed by the bypass doors, which reconfigured the inlet to its optimum performance. "Unstarts" were a regular feature of early A-12 flights, but as

The two-seat AT-12T dedicated pilot trainer was powered throughout its life by two Pratt & Whitney J75 engines, which were considerably less powerful than the twin J58s that equipped the single-seat variant. The trainer therefore lacked the ability to cruise at Mach 3+. (Lockheed Martin) computer software improved a system known as the Digital Automatic Flight and Inlet Control System (DAFICS) was developed for the SR-71. The DAFICS was able to achieve near-perfect inlet airflow control, which in turn practically rid the jet of its "unstart" problems.

Stability Augmentation System

The A-12's center of gravity (CG) was automatically moved aft during acceleration to high-Mach flight, to reduce trim drag and improve elevon authority in both the pitch and roll axes. The fuselage chine produced lift forward of the center of gravity, which had the effect of destabilizing the aircraft in the pitch axis and reducing aft CG travel, resulting in low static margins of stability and safety. Additionally, the chine had an adverse aerodynamic effect on the aircraft when performing sideslip maneuvers at cruise angles of attack (approximately 6 degrees of positive alpha). This, coupled with low aerodynamic damping – inherent with flight at high altitudes – conspired to make the A-12 only marginally stable in both pitch and yaw at high Mach.

Control in this delicate but critical corner of the flight envelope was achieved by the aircraft's elevons and rudders, which were worked through an automatic flight control system (AFCS). The AFCS consisted of a redundant three-axis stability augmentation system (SAS), a two-axis autopilot, an air data computer, and a Mach trim system. Other associated equipment included an inertial navigation system (INS), a flight reference system (FRS), hydraulic servos, and a pitch actuator. The AFCS provided pitch, roll, and yaw stabilization via the flight control surfaces. Eight rate-sensing gyros detected divergence from stable flight and together with three lateral accelerometers, also provided motion-sensing signals relative to the rate of change in all three of the aircraft's axes, thus damping excessive changes in attitude. Because these SAS corrections were applied through a series of servos, they weren't apparent to the pilot at the control stick or rudder. Control over the AFCS was provided to the pilot via "Pitch SAS," "Roll SAS," and "Yaw SAS" switches, located on the right-console panel. The servos could also be activated by direct stick and rudder-pedal inputs.

Although the A-12 was highly advanced, the cockpit instrumentation and its layout were very unspectacular and straightforward. The hooded view scope can be seen at the top of the picture. (Roadrunners Internationale)

The two-channel (pitch and roll) autopilot processed INS and FRS inputs, then applied the data through the SAS electronics to transfer valves for control surface positioning. This provided the autopilot with two separate "hold functions." Pitch control was achieved via the basic attitude hold mode, Knots Equivalent Airspeed "hold," or Mach "hold." In roll mode, control was exercised via the basic roll attitude hold mode, heading hold mode, or auto-steering "Auto Nav" mode; this latter mode was programed to obey heading commands from the INS. When the autopilot was engaged, the aircraft was held in the roll attitude established at the time of engagement. With "Auto Nav" selected, the autopilot controlled roll to ensure that the aircraft adhered to the predetermined navigation track that the INS accurately maintained. During operational sorties the aircraft was invariably flown in this mode to ensure that it remained stable and on an accurate track whilst the onboard sensors were activated.

The Mach trim system provided speed stability up to Mach 1.5, while the aircraft was either accelerating or decelerating – a period during which the autopilot could not be engaged. It compensated, via the pitch trim actuator, for the aircraft's propensity to "tuck" nose-down while accelerating through the Mach and rise nose-up while decelerating.

Inertial Navigation System (INS)

The A-12's INS was completely self-contained and provided the principal navigation references to the aircraft without recourse to any electromagnetic radiation or other external references. The system provided attitude, true heading, command course, ground speed, distance, and geographic position data for automatic or manual navigation between waypoints on the flight plan. The pilot could, if required, update position information periodically to correct gyro drift by taking fixes with a view scope that provided an optical display of the terrain along the flight path, or by taking sun fixes with an optical device to measure the sun azimuth angles for determination of true heading.

The flight reference system provided magnetic heading information and served as an alternate navigation reference. A gyromagnetic compass provided both slaved gyro and free gyro heading information, while a gyro platform provided pitch and roll information.

A set of integrated flight instruments consisting of an attitude indicator, a bearing-distance-heading indicator and related signal-switching equipment, displayed navigation information to the pilot. The indicators operated in conjunction with the inertial navigation and flight reference system to provide data to the pilot.

Mission sensors

View scope

Inside the cockpit a large view scope, located in the center of the front instrument panel, enabled the pilot to select several different functions. Utilizing a Baird-Atomic 6642-1 periscope system, it was possible to view the ground below. The scope had two settings: a wide-angle field of view, about 85 degrees forward of nadir (a point on the earth's surface directly below the aircraft); and a narrow field of view, which provided coverage of about 47 degrees forward of nadir. An upwards view function enabled sun compass readings to be taken to cross-check the INS. Additionally, a route filmstrip could be selected, providing the pilot with a visual reference of the aircraft's progress or other pictorials like let-down plates for landing.

Cameras

Although three different cameras were developed for the Oxcart program, only the Perkin-Elmer Type I camera was used during operational missions. Equipped with an f/4.0, 18in lens, image frame size was 27.6×6.3in. The unique camera system or "package" utilized two reflecting cube

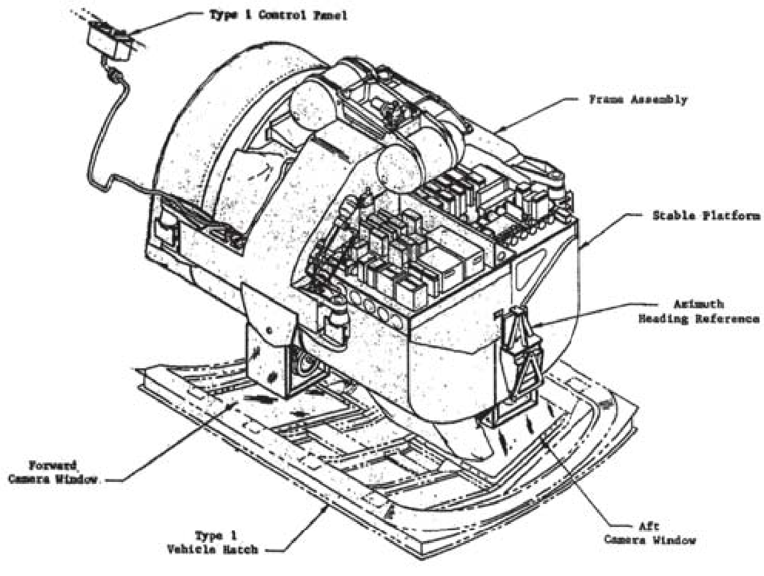
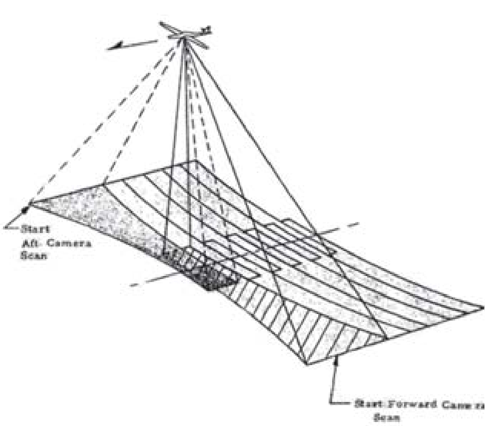


Figure 1-4. Q-Bay Pakcage Type I, Physical Description.

The essence of Project Oxcart was the Type I camera, manufactured by Perkin-Elmer. The inner works of this very complex camera system remain highly sensitive and even after nearly 50 years, no detailed photographs of the unit have yet emerged. (CIA Pilots Manual)

scanners, positioned one behind the other, enabling imagery to be scanned simultaneously onto either the left or right film spool. The forward unit scanned from 21 degrees to the right of vertical, then out to 67 degrees to the left; the aft scanner rotated 21 degrees left from the vertical, then out to 67 degrees to the right – thereby providing 42 degrees of stereo coverage directly below the aircraft, and a total swath 134 degrees wide (which from 80,000ft was 72 miles). The scan cycle time was 4.8 seconds and each frame was timed to produce a 30 percent overlap. Ground resolution was 1ft at nadir (80,000ft vertically below the aircraft) and 3ft, depending upon haze degradation at the outer edges of the image – that's 36 miles left or right of the Oxcart's track. Transport of the 5,000ft of film within the camera utilized a concentric supply and take-up system to ensure that film weight remained centralized, thereby minimizing potential changes in the aircraft's CG as the film advanced.

Because in-flight temperatures could vary between –40 and +290 degrees C, an isothermal window was provided as a protective barrier between such severe temperature gradients and the camera's film. This window was sealed to the Type I camera and a pump was then used to create a vacuum between the camera base and the glass. The entire camera assembly was lowered through a removable hatch into the Q Bay; the camera lens sought out its targets through the high-quality quartz window that measured 22in×23in. Problems encountered when bonding the window to its metal frame were eventually overcome during a three-year, $2 million program, which developed a unique fusing process using high-frequency sound waves.



The forward and aft scanning heads of the Type I camera provided a level of stereo overlap directly below the aircraft before each then scanned out to the left and right, 67 degrees either side of the Oxcart's track. (CIA Pilots Manual)

Birdwatcher

Birdwatcher was a monitoring system unique to the A-12. It utilized a multiplexed High Frequency, Single Side-Band (HF/SSB) radio system and was designed to telemeter signals concerning the operation/non-operation of various aircraft systems down to a specially equipped ground station. The frequencies selected for any particular mission were briefed and noted by the pilot on hand-cards; they were also annotated on the mission filmstrip, which was displayed to the pilot in the cockpit. The system consisted of two main elements: an air element and a ground element. The air element was a subset of the aircraft's HF/SSB radio, the antenna consisting of a tube structure within the aircraft's pitot/static system located at the front of the aircraft. The relatively short antenna was closely matched to the ground plane, furnished by the airframe, and made a fairy efficient antenna. Of its 40 channels, 32 were used to monitor individual aircraft systems; for example, channel 54 covered the starboard engine's EGT; channel 7, the starboard engine's fuel flow; while channel 3 covered the aircraft's altitude. If any pre-set parameters of the systems being monitored were breached, Birdwatcher keyed and modulated the HF transmitter with a coded signal consisting of three consecutive half-second bursts, each separated by a five-second period of silence. During each of the half-second bursts, the aircraft's identity and the condition of each of the systems being monitored was transmitted. These three bursts could be heard through the pilot's headphones as three chirps – hence the name Birdwatcher.

The A-12 pilot had only limited control over the system. In the cockpit there were two switches; these were labeled "A" and "B." The "A" code was usually used by the pilot to signify to the ground station that the aircraft had reached a pre-designated point in the mission and that it was in a "GO" condition, such as at the end of a successful air refueling, or upon reaching a predetermined distance-to-go point or turn point. The pilot activated the "B" code usually to indicate that the aircraft had experienced some sort of abort condition. The two buttons could be used sequentially to indicate that something unusual had occurred; for example, "B" followed by "A" might be interpreted as meaning that the aircraft had an abort condition, but was not in an emergency situation. Involuntary Birdwatcher codes were transmitted automatically by the system when any one of a number of sensors tripped the encoder. All radio emitters on the A-12 could be inhibited by the pilot by activating a "Mute" switch – except the Birdwatcher. The Mute system was installed on the aircraft to prevent accidental transmissions by a device such as the Tacan, UHF radio, etc. The pilot was usually instructed to operate the Mute switch by the mission filmstrip prior to entering denied territory.

Birdwatcher could also be interrogated by appropriately equipped ground stations. The Command Post (CP) could, if required, cause Birdwatcher to transmit a short burst of information that would include only the coded identification of the Oxcart – if no other sensors had already tripped. To the dismay of a couple of pilots, some of those monitoring the aircraft's progress from the ground station at Kadena AB occasionally interrogated the aircraft when it was over enemy territory!

The ground station for Birdwatcher at Area 51 was located just outside the entrance to the CP, in the Secure Communications Room – a highly restricted area. From here, an operator monitored the Birdwatcher decoder using an oscillograph-paper recorder upon which was recorded the Birdwatcher's "chirping." Lights were then used to develop the oscillograph paper to a point where it was possible that the technician could place the paper on a readout cursor and see which sensor had tripped. He then activated a switch that illuminated an appropriate light on a light board located in the CP, thereby alerting other officers as to the aircraft's status.

ELINT

The A-12 was also equipped with an electronic intelligence (ELINT) capability, known as System 6. This wide-band collection system comprised a miniaturizing wide-frequency receiver which monitored C, L, X, and P bands. These were then split and recorded by two three-channel recorders working at 2¼ inches

Parked up on the north ramp, an early shot during the Oxcart test program reveals seven A-12s, the AT-12 trainer, and at the far end two YF-12A interceptors. (Lockheed Martin)

per second; C and X band information, together with capture time and left or right of track directional information, was channeled to one recorder, whilst the same data for L and P bands was stored by the other unit.

ECM

All systems were activated by a single, three-position power switch labeled OFF, Standby, and ON. There was also a built-in-test (BIT) switch that activated a logic test to ensure that each element worked correctly. These checks were undertaken by the pilot prior to entering denied territory; satisfactory completion of the checks caused the Birdwatcher to chirp, which confirmed to the ground station that the aircraft was about to penetrate hostile airspace. If the BIT check failed, it was mandatory for the pilot to abort the mission – in God and ECM we trust!

The only elements of the system that were visible to the pilot were a series of five lights positioned above the view scope and enclosed in the cockpit glare shield. The outboard lights were marked DF, the set inboard of these were marked LI, and the larger center light was known as the JAM GREEN or JAM RED light. The DF lights illuminated when the ECM system detected that a SAM target acquisition system was tracking the Oxcart. If only one of these two lights were on, it indicated the general direction of the tracking radar; if both were on it meant that the SAM system was either ahead or on both sides of the flight path. The LI lights illuminated when the SAM site's radar had gone into a high PRF (pulse repetition frequency) mode and usually indicated that the SAM site had actually launched one or more missiles. Frank Murray recalls the usual sequence of events:

> When a SAM site was on you, the DF light or lights would come on and this started the Birdwatcher chirping. Then the LI light[s] would come on, indicating a missile launch. Then came the moment of truth! Sometime into the missile flight-time, the

> active parts of the ECM suite would activate and the JAM GREEN light would illuminate. This indicated to the pilot that the ECM system was working to counter the missile's guidance system. If however the JAM RED light illuminated, this indicated that the active elements of the system weren't working correctly, in which case the pilot then had to depress and hold-down a button marked JAM O'RIDE [JO], located on the top-right portion of the flight control stick. This activated the noise-jammer part of the ECM suite – I have to say though, that I'm not aware of anyone in the program having to use the JO button.

The various elements of the ECM suite were given cryptic names. Pin Peg was a radar homing and warning (RHAW) receiver, and monitored S- and C-band frequencies to indicate the presence and approximate position of Fan Song SA-2 target acquisition radars; if required, it also activated the jammer. Blue Dog II was the hardware that provided Oxcart with the protective element of the ECM suite. It was a large deceptive radar countermeasure system weighing in at 480lb, and required power output of 20kW and antenna gain greater than 79dBm. Utilizing a technique known as range gate pull-off, it deceived the SA-2's missile guidance system by generating false guidance commands. Pin Peg and Blue Dog II were used in association with either Big Blast or Mad Moth. Big Blast also covered both S and C bands, generating, when required, barrage and deceptive noise protection against SA-2s; Mad Moth provided protection in S and C bands against SA-2s by using angle deception.

Crew Survival Systems

Emergency escape from the A-12 was via an ejection seat; but due to the extreme altitudes at which the aircraft flew, pilots were required to wear full pressure suits. In the event of ejection or cockpit decompression, the suit provided protection against many physiological problems that, if left unchecked would kill the crewman in minutes. The multi-layered suits were tailor-made for each Oxcart pilot and manufactured by the David Clark Company of Worcester, Massachusetts. The suits were designated S-901A through H, and initially featured an aluminum-impregnated coverall, but this was later changed to white to reduce reflections within the cockpit.

A-12 PROJECTS AND VARIANTS

Mach 3 mothership: Project Tagboard and the M-21/D-21

Following the loss of Powers' U-2 and the US Government's subsequent decision to discontinue manned overflights of China and the Soviet Union, on October 10, 1962 the Skunk Works received authorization to begin studies into the feasibility of producing a Mach 3+ unpiloted platform, or drone, for the CIA. Initial flight tests of the A-12 had given the design team working on the drone – designated Q-12 at this early stage – considerable confidence in the aerodynamic precedent set by the chined delta, and this configuration was applied to the vehicle as it took shape. Powered by a high-speed ramjet, experience about which Lockheed was able to draw upon from their involvement in the X-7 program, the engine was built by Marquardt and designated the XRJ43-MA20S-4. To provide the necessary propulsive power to start the ramjet, the drone would be launched at Mach 3.13 from a modified

Kelly Johnson highlighted both the cost and dangers of launching the D-21 from the M-21 at Mach 3+ and, following a fatal collision between the pair on July 30, 1966, two modified B-52Hs were used. However, Project Senior Bowl was both expensive and unsuccessful; it was canceled as Project Corona, the US satellite program, became more reliable. (Lockheed Martin)

A-12. A Launch Control Officer (LCO) was located in what was formally the A-12's Q Bay, reconfigured for the purpose. Two A-12s were modified for these duties: Articles 134 (60-6940) and 135 (60-6941). This mother–daughter combination gave rise to their redesignation as M-21 (Mother) and D-21 (Daughter-drone); the numerical designation was also transposed to avoid all confusion with the Oxcart A-12. The drones were considered "one-way aircraft," meaning that they would make one flight only, after which the palletized unit containing the platform's INS, together with the reconnaissance camera (built by Hycon) and its all-important film, would be ejected over safe international waters and recovered during the parachute descent by means of a Mid-Air Recovery System (MARS). The remainder of the drone would then self-destruct, using an explosive charge, and its remains would fall into a watery grave.

On August 12, 1964, D-21 number 501 was sent from Burbank to Area 51, where satisfactory static tests were subsequently concluded. On December 22, 1964, the first D-21/M-21 combination flight was successfully completed. Having surmounted a number of technical difficulties, the two-aircraft combination was flown out to Mach 2.6 in May 1965; however, it wasn't until October 21 of the same year that the team were finally able to get the M-21 up to the required launch speed, this being achieved by installing the new 34,000lb-thrust J58 engines. Delays continued, but finally on March 3, 1966, the first D-21 launch was accomplished. The drone crashed into the Pacific 120 miles after vehicle separation, but at least the launch technique had been successfully demonstrated. The second flight took place on April 27 and was a brilliant success, the D-21 achieving a range of 1,200nm – holding course to within half a mile – a speed of Mach 3.3, and an altitude of 90,000ft. The drone finally fell from the sky after a hydraulic pump burned out. Significantly, at this point Johnson proposed substituting the M-21 mother-ship for a Boeing B-52 Stratofortress, and utilizing a rocket to boost the drone up to ramjet speed and altitude.

Having successfully demonstrated the concept, a second order duly arrived on April 29 for 15 D-21s. Johnson formally proposed that SAC should launch

C

M-21/D-21

M-21 Article 135 (serial 60-6941) was destroyed during the fourth D-21 launch, when the drone collided with its mothership during the separation maneuver. Both crewmen ejected safely over the Pacific, but tragically LCO Ray Torick then drowned when his pressure suit filled with water.

When President Eisenhower committed not to undertake further manned reconnaissance overflights of the Soviet Union, use of the M-21/D-21 mother/drone combination in Project Tagboard was seen as a possible way to obtain reconnaissance data yet remain true to the President's pledge. (Lockheed Martin)

the drone from a B-52H on the basis of "greater safety, lower cost and greater deployment range" – this proved prophetic.

The third launch, on June 16, went well, with the drone clocking up 1,600nm and completing eight programed turns. However, disaster struck on July 30 when, during the course of the fourth flight, D-21 number 504 collided with M-21 Article 135 during the separation maneuver. At Mach 3.25 the M-21 pitched up, the aircraft's forward forebody broke off and despite both crewmembers successfully ejecting, the LCO, Ray Torick, tragically drowned in the subsequent feet-wet landing after his pressure suit filled with water.

Following a meeting in Washington, DC on August 15, 1966, it was decided that Project Tagboard would be canceled. During the subsequent D-21 grounding that lasted a year, a new program codenamed Senior Bowl was initiated. Two B-52Hs belonging to the 4200th Test Wing at Beale AFB in California were converted to act as launch platforms. The D-21s (as earlier envisaged by Johnson) utilized a rocket booster like the X-7's to blast the drone to speed and altitude before separating and falling into the ocean. However, like its predecessor, Tagboard, results of Senior Bowl were at best questionable and the program was eventually canceled on July 23, 1971, by which time satellites were proving to be far more reliable and cost-efficient.

Project Kedlock: the YF-12 interceptor

Spurred on by the earlier success of his A-12 design for the CIA, Kelly Johnson discussed the possibility of building a long-range interceptor version for the Air Force, during a meeting on March 16–17, 1960, with Gen Hal Estes of Air Force Systems Command and Dr Courtland Perkins, the Air Force Secretary for Research and Development. Referred to as the AF-12, the idea was keenly received and subsequently forwarded to Gen Martin Demler, at Wright-Patterson AFB, for further discussion and analysis. During late October 1960, Lockheed received a letter of intent for $1 million and was directed to "go forward with Plan 3A" and produce an interceptor version of the A-12 equipped with the Hughes ASG-18 Fire Control System (FCS) and the GAR-9 missile (both radar and missile systems had already been developed for the USAF North American F-108 Rapier, which had been subsequently canceled on September 23, 1959 due to escalating costs). The program was accorded the classified codename Kedlock, and the seventh A-12 was nominated to become the AF-12 prototype.

The modified A-12 accommodated a fire control system operator in a second cockpit, similar to the M-21. The forward fuselage chines were cut back to incorporate a radome that housed a 40in-diameter scanning dish, and four weapons bays were cut into the underside to house the FCS in the forward right bay and a GAR-9 missile in each of the other three bays. But by June, wind tunnel tests revealed that these modifications had resulted in directional stability problems. To alleviate these, two fixed ventral fins were installed on the underside of each engine nacelle. In addition, a large sideways-folding fin was mounted at the rear of the aircraft's centerline. Retraction and extension of the folding fin worked out of phase with the cycling of the landing gear – as the gear retracted, the fin extended and vice versa.

Concurrent to activity on the AF-12, a two-seat bomber version of the A-12, referred to as the RB-12, was also being studied. A full-scale mock-up of the forward fuselage was built and then reviewed by Gen Curtis LeMay and Gen Thomas Power on July 5, 1961; but despite considerable interest, this program would prove to be stillborn.

In total, three AF-12s were constructed, with the maiden flight of the prototype being conducted by Lockheed test pilot Jim Eastham from Area 51 on August 7, 1963. To draw attention away from the covert CIA A-12 program, President Lyndon Johnson announced the existence of the "A-11" at Edwards AFB on February 29, 1963. The "A-11" title was a deliberate piece of deception engineered by Kelly Johnson; but with the AF-12 now assigned an official Air Force designation (YF-12A), this further compounded the confusion!

Test flights of the new interceptor from Edwards AFB continued with increased frequency and confidence and on April 16, 1964, the first missile – now designated AIM-47 – was ejected in flight. Between March 18, 1965 and September 21, 1966, the three YF-12As fired a total of seven AIM-47s. The final mission (G-20), flown in YF-12A 60-6936, successfully intercepted a QB-47 remotely piloted target drone whilst cruising at Mach 3.2 and an altitude of 74,000ft – the target drone was at sea level!

Aerospace Defense Command officials calculated that 96 F-12B production aircraft could replace its entire fleet of Convair F-102 Delta Dagger and F-106 Delta Dart interceptors and provide protection for the entire United States against incoming Soviet high-speed, low-level bombers; but it wasn't to be. Instead, political shenanigans and a long-simmering feud over the appropriation of defense funds between Secretary of Defense Robert McNamara and the Air Force resulted in McNamara denying $90 million worth of funds that had been appropriated by Congress to begin F-12B production. These delaying tactics played out by McNamara eventually paid off and on January 5, 1968, the Skunk Works finally received official notification from the Air Force to close down the F-12B production line. To seal the fate of future Mach 3 aircraft production, Johnson received a letter from the Air Force dated February 5, 1968, instructing Lockheed to destroy the A-12/F-12 tooling, including that used in SR-71 production. In a later response the designer wrote, "We have proceeded to store such items as are required for producing spare parts at Norton. The large jigs have now been cut up for scrap and we are finishing the clean-up of the complete area. Ten years from now the country will be very sorry for taking this decision of stopping production on the whole Mach 3 series of aircraft in the USA."

YF-12A records

It is probably no coincidence that the date chosen to demonstrate some of the YF-12A's awesome capabilities was May 1, 1965 – five years to the day since Gary Powers was shot down by a Soviet SA-2 during a U-2 overflight. It should also be noted that as impressive as the figures below are, they are not demonstrations of the airplane's absolute capabilities. For example,

Note the cut-back chine of the YF-12A to accommodate a radome within which was located a 40in-diameter scanning dish for the AN/ASG-18 radar. The GAR-9 or AIM-47 radar-guided air-to-air missile sits on its trolley. The three AIM-47 mission marks below the cockpit indicate that this aircraft is Article 1003 (60-6936), it having participated in three missile firings. (Lockheed Martin)

on November 20, 1965, an A-12 attained speeds in excess of Mach 3.2 and a sustained altitude capability above 90,000ft. During the first operational deployment of a CIA A-12, from Area 51 to Kadena Air Base on the island of Okinawa, pilot Mele Vojvodich covered the distance in Article 131 (60-6937) in just six hours, six minutes; had it not been for security considerations, this could easily have been recognized as a new trans-Pacific speed record.

On May 1, 1965, Article 1003 (60-6936), crewed by Col Robert L. "Fox" Stephens and Fire Control Officer (FCO) Lt Col Daniel Andre, simultaneously achieved an absolute altitude record of 80,257ft and an absolute speed over a straight course of 2,070.101mph. Lt Col Walter F. Daniel and FCO Maj James P. Cooney took 60-6936 to a speed of 1,688.889mph over a 500km closed course and the same crew got the 1,000km closed course record in 60-6936 at 1,643.041mph.

SR-71

The final variation of the A-12 design was of course the legendary SR-71, but this will be covered in depth in a separate Air Vanguard volume.

D

YF-12

The YF-12 interceptor's cockpit canopy was higher than that of the single seat A-12, due to the slightly wider forward fuselage to accommodate the large radar scanning dish housed within the radome. It was equipped with the very long range AIM-47 Falcon missile (later to be developed into the naval AIM-54 Phoenix) and Hughes AN/ASG 18 fire control system, both of which had been developed for the canceled XF-108 Rapier.


USAF
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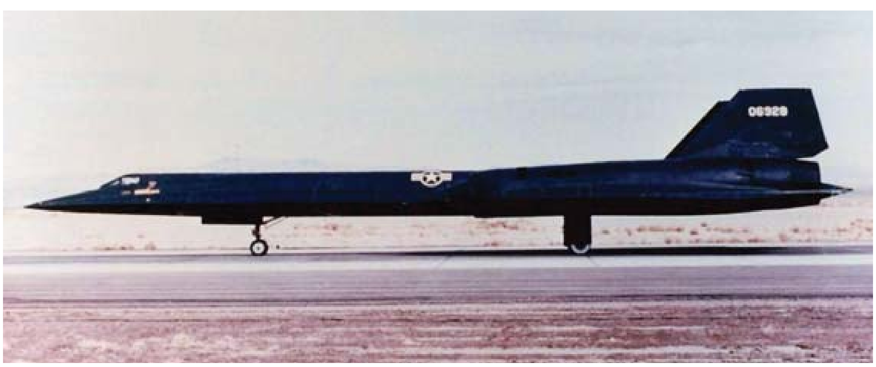
OPERATIONAL HISTORY

Since the May 1, 1960 U-2 shoot-down, successive US Presidents continued Eisenhower's pledge not to sanction manned overflights of the Soviet Union. The loss of Maj Rudy Anderson's U-2 to an SA-2 over Cuba both highlighted the aircraft's vulnerability and vindicated the decision to build a replacement, but still the question remained: where could Oxcart, this highly sophisticated, multi-million-dollar program, be deployed?

One possible mission arose in 1964, when KH-4 Corona satellite imagery obtained what some analysts believed was an antiballistic missile site, located at Tallinn in Estonia. The Office of Special Activities (OSA) proposed that a composite mission should be flown consisting of a camera-equipped Oxcart, and a U-2 configured for gathering ELINT. The highly classified proposal had the classified cryptonym Project Upwind. The plan was to fly the A-12, with air refueling support, from the United States to the Baltic Sea, where it would rendezvous with the U-2. The Oxcart would then fly down the Baltic Sea, skirting the coasts of Estonia, Latvia, Lithuania, Poland, and East Germany before heading back west to the United States. The 11,000-mile flight would take eight hours, 40 minutes to complete and require four air refuelings. Remaining outside Soviet airspace, it was hoped that the high-speed, high-altitude target would provoke Soviet radar operators into activating the Tallinn system. The A-12 would secure high-resolution imagery of the Tallinn site whilst the more vulnerable U-2 would be standing off, beyond SA-2 range, recording the radar's signal characteristics. Both Agency and Defense Department officials supported the proposal; however, Secretary of State Dean Rusk was strongly opposed and the influential 303 Committee never forwarded the proposal to President Johnson for his approval.

Another possible area of operations for Oxcart was Cuba. By early 1964, Project Headquarters had already begun planning for possible "contingency overflights" under a program codenamed Skylark. Four of the 13 A-12s then at Area 51 were initially designated as primary Skylark aircraft, namely Articles 125, 127, 128, and 132, and they were later joined by Articles 129 and 131 following the installation of further modifications.

A meeting on September 15, 1964 between Secretary of State Dean Rusk, Secretary of Defense Robert McNamara, National Security Advisor McGeorge Bundy, and DCI John McCone, discussed the limitations of satellite coverage of Cuba in the context of monitoring assurances made by the Soviet Union following the 1962 missile crisis not to redeploy nuclear missiles on the island. The discussion also covered the vulnerability of the U-2 to undertake such missions in the light of past events and the very real



When deployed to Kadena AB on the island of Okinawa during Black Shield, the three Oxcarts wore an all-black paint scheme with no national insignia and a dark red, bogus serial number applied to the tail. Article 125 (60-6928) was not one of the three aircraft deployed on operations as it had crashed, with the loss of its pilot, Walt Ray, on January 5, 1967. (Lockheed Martin)

SAM threat. It was agreed that Oxcart overflights would be less vulnerable than the U-2, but not entirely invulnerable. McNamara believed that one flight every 30 days would provide enough coverage of the island to fulfill the United States Intelligence Board requirements; but others in attendance disagreed, particularly on the number of sorties required, given a study of the history of weather over Cuba. The parties adjourned, agreeing that the subject should receive further study that should include Oxcart vulnerability under the Skylark program and a substantive judgment as to the number of flights required from November 1964 to November 1965 in order to accomplish acceptable coverage of the island with usable photography.

To bring the A-12s up to the necessary standard required to participate in the envisaged missions, a two-point plan was developed, and both Phase I and Phase II were to begin simultaneously on March 1, 1965. Phase I focused on increasing the aircraft's speed envelope out from Mach 2.9 to Mach 3.05; Phase II concentrated on providing Oxcart with the capability to undertake three air refuelings during the course of a mission and an element, codenamed Supermarket, related to improvements in the A-12's ECM system. As an interim, on August 5, 1965, the Director of the National Security Agency, Gen Marshall S. Carter, directed that Skylark was to achieve emergency operational readiness by November 5. Should security considerations dictate, any contingency sorties would have to be executed below the optimum capability of the A-12 – nearer to Mach 2.8. In order to meet this tight timeframe, the Oxcarts would have to deploy without their full ECM suite; but despite all the difficulties, a limited Skylark capability was ready on the prescribed date. In the event, these Cuban contingencies were never implemented: on September 15, 1966, the 303 Committee voted not to commit Oxcart to Cuban reconnaissance missions, on the basis that it could disturb the prevailing political calm. Instead, a more critical situation developing in Southeast Asia took priority.

Mele Vojvodich, pictured in his David Clark S-901 full pressure suit, was the first to deploy an Oxcart to Kadena AB and also the first to fly an operational mission – BX001 on May 31, 1967. (CIA)

Black Shield

On March 22, 1965, Brig Gen Jack Ledford, Director of the CIA's Office of Special Activities, briefed Deputy Secretary of Defense Cyrus Vance on Project Black Shield – the planned deployment of Oxcart to Okinawa, in response to the increased SA-2 threat facing U-2s and Firebee drone reconnaissance vehicles. Secretary Vance was willing to make $3.7 million available to provide support facilities at Kadena AB, which were to be ready by the fall of 1965. On June 3, 1965, Secretary of Defense McNamara consulted with the Under Secretary of the Air Force on the build-up of SA-2 missile sites around Hanoi and the possibility of substituting A-12s for the vulnerable U-2s on recce flights over the North Vietnamese capital. He was informed that Black Shield could operate over Vietnam as soon as adequate aircraft performance was validated.

On November 20, 1965, Bill Park completed the final stage of Project Silver Javelin, the Oxcart validation process, with a maximum-endurance flight of six hours and 20 minutes, during which time he demonstrated sustained speeds above Mach 3.2 at altitudes approaching 90,000ft.

A rearward-facing cine camera was mounted behind the cockpit of the three Black Shield Oxcarts, the idea being to film SA-2 attacks, although it isn't known if any footage was ever captured during at least three of the known incidents. In this picture the aircraft is seen at speed and altitude – note the position of the fully retracted spike to produce the maximum inlet capture area. (Roadrunners Internationale)

Four A-12s were selected for Black Shield operations, Kelly Johnson taking personal responsibility for ensuring that the aircraft were completely "squawk-free." On December 2, 1965, the highly secretive 303 Committee received a formal proposal to deploy Oxcart operations to the Far East. The proposal was quickly rejected, but the Committee agreed that all steps should be taken to develop a quick-reaction capability for deploying the A-12 reconnaissance system within a 21-day period anytime after January 1, 1966.

Throughout 1966, numerous requests were made to the 303 Committee to implement the Black Shield Operations Order, but all requests were turned down. A difference of opinion had arisen between two important governmental factions that advised the Committee: the CIA, the Joint Services Committee, and the President's Foreign Intelligence Advisory Board favored the deployment; but Alexis Johnson of the State Department, Robert McNamara and Cyrus Vance of the Defense Department opposed it.

Whilst the political wrangling continued, mission plans and tactics were prepared to ready the operational "package" for deployment should the Black Shield plan be executed. Deployment timing was further cut from 21 to 11 days, and the Okinawa-based maintenance facility was stocked with support equipment. To further underwrite the A-12's capability to carry out long-range reconnaissance missions, Bill Park completed another nonstop sortie, this time of 10,200 miles in just over six hours on December 21, 1966. But misfortune struck the program again on January 5, 1967, when, due to a faulty fuel gauge, Article 125 was lost some 70 miles short of Area 51. The CIA pilot Walt Ray ejected safely, but tragically was unable to gain seat-separation and was killed on impact with the ground.

In May 1967, the National Security Council was briefed that North Vietnam was about to receive surface-to-surface ballistic missiles. Such a serious escalation of the conflict would certainly require hard evidence to substantiate such a claim; consequently President Johnson was briefed on the threat. DCI Richard Helms again proposed that the 303 Committee authorize deployment of Oxcart, as it was ideally equipped to carry out such a surveillance task on the grounds of having both superior speed and altitude to U-2s and pilotless drones, as well as a better camera. President Johnson approved the plan and in mid-May an airlift was begun to establish Black Shield at Kadena AB.

At 0800hrs on May 22, 1967, Mele Vojvodich departed from Area 51 in Article 131 and headed west across California for his first refueling. Having topped-off, he accelerated to high Mach toward the next Air Refueling Control Point near Hawaii. A third rendezvous took place near Wake Island to ensure that he had enough reserve fuel to divert from an intended landing at Kadena AB to either Kunsan AB in South Korea or Clark AFB in the Philippines, should the weather over Okinawa deteriorate. When Vojvodich arrived at Kadena AB, however, the weather was fine and he let down for a successful landing after an uneventful flight of just over six hours' duration.

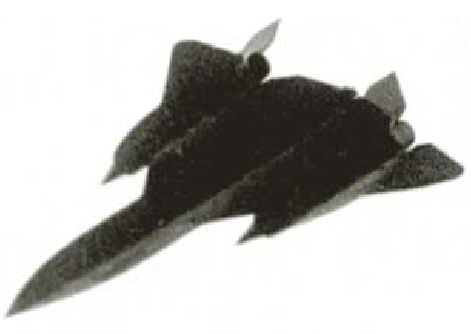
Two days later, Jack Layton set out to repeat Vojvodich's flight in Article 127 (60-6930); and Jack Weeks followed in Article 129 (60-6932) on May 26. However, due to INS and radio problems, Weeks was forced to divert into Wake Island. An Oxcart maintenance team arrived in a KC-135 from Okinawa the following day to prepare Article 129 for the final "hop" to Kadena AB. After completing the journey, Weeks' aircraft was soon declared fit for operational service along with Articles 127 and 131. As a result, the Detachment was declared ready for operations on May 29 and, following a weather reconnaissance flight the day after, it was determined that conditions over North Vietnam were ideal for an A-12 photo-run.

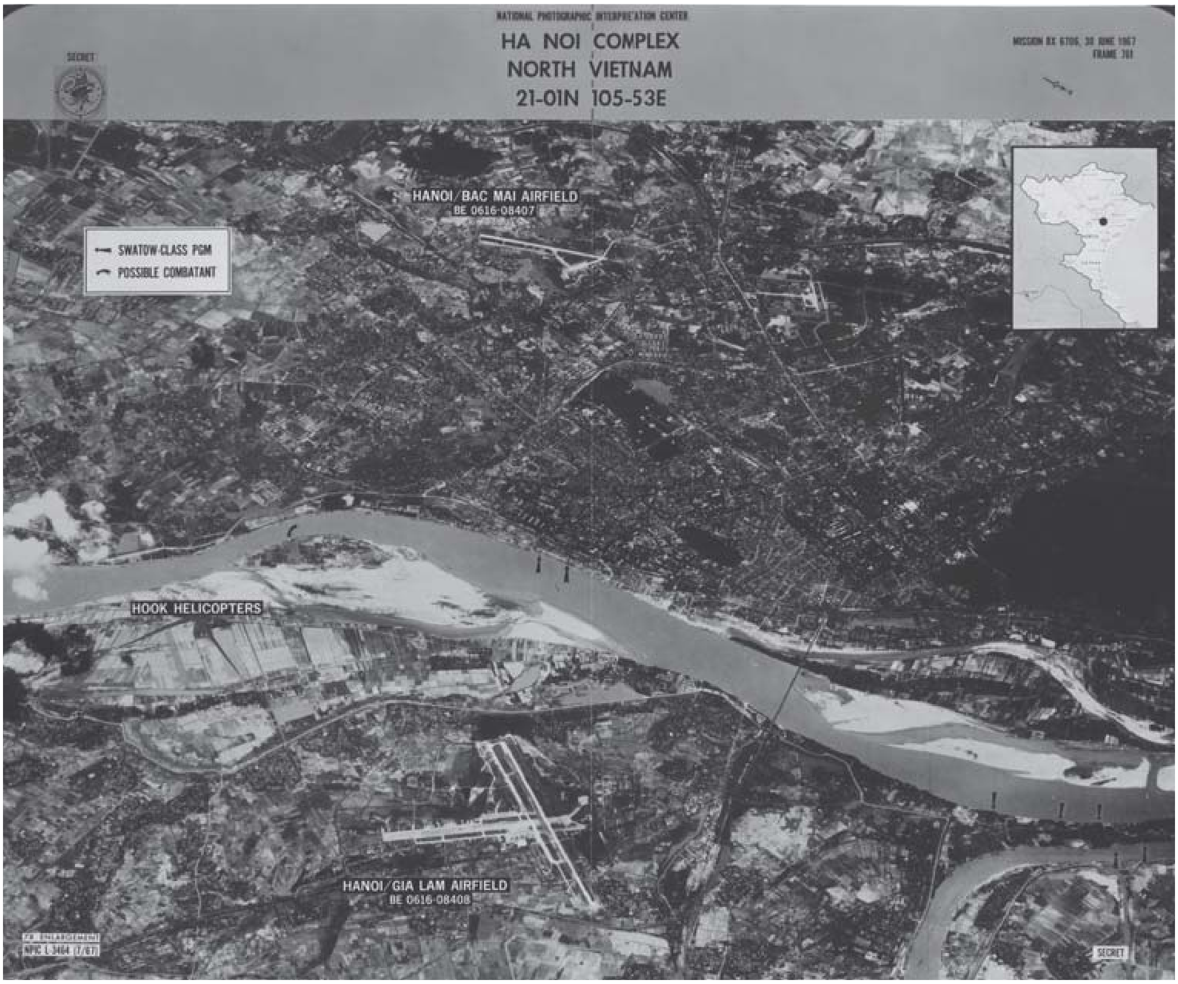
Project Headquarters in Washington, DC then placed Black Shield on alert for its first ever operational mission. Avionics specialists checked various systems and sensors, and at 1600hrs Mele Vojvodich and back-up pilot Jack Layton attended a mission alert briefing that included such details as the projected take-off and landing times, routes to and from the target area, and a full intelligence briefing of the area to be overflown. At 2200hrs (12 hours before planned take-off time) a review of the weather confirmed the mission was still on, so the pilots went to bed to ensure they got a full eight hours of "crew rest."

They awoke on the morning of the 31st to torrential rain, but the two pilots ate breakfast and proceeded to prepare for the mission. Despite local meteorological conditions, the weather over "the collection area" was good, so at 0800hrs Kadena received a final clearance from Washington, DC that Black Shield flight BX001 was definitely "on." Following brief medical checks, the two pilots donned their S-901 full pressure suits and began breathing 100 percent pure oxygen to purge their bodies of potentially harmful nitrogen. By taxi-time, the rain was falling so heavily that a staff car had to lead Vojvodich's aircraft from the hangar to the end of the main runway. After lining up for what would be the first instrument-guided take-off, on cue both afterburners were engaged and Article 131 accelerated rapidly down the runway to disappear completely into the rain and then upward, through the drenching clouds.

A few minutes later, Article 131 burst through cloud and climbed to 25,000ft to top-off its tanks from the waiting KC-135Q tanker. Once disengaged from the tanker's boom, Vojvodich accelerated and climbed to operational speed and altitude having informed Kadena ("home-plate") that the aircraft systems were running as per the book and the backup services of Jack Layton would not be required. Vojvodich penetrated hostile airspace at Mach 3.2 and 80,000ft during a so-called "front door" entry over Haiphong, then continued over Hanoi before exiting North Vietnam near Dien Bien Phu. A second air refueling took place over Thailand, followed by another climb to speed and altitude, and a second penetration of North Vietnamese airspace made near the Demilitarized Zone (DMZ), after which

The only pictures to have emerged to date of Oxcart's participation in Black Shield are these two grainy images taken from 8mm black and white cine film shot, ironically, by the CIA's station head of security. (Roadrunners Internationale)

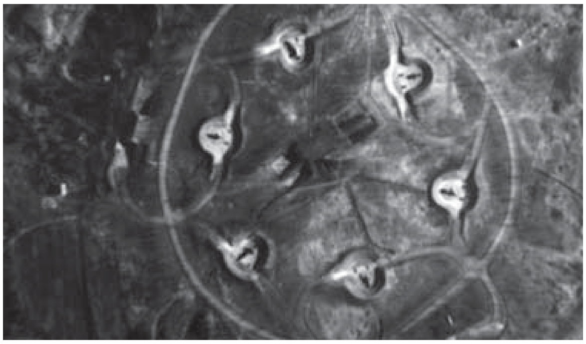


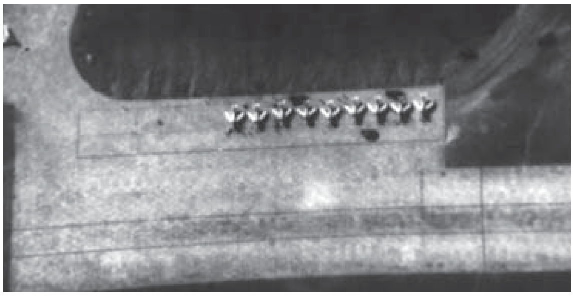


Frame 761, analysed at NPIC, was taken during mission BX6706 on 30 June 1967, by Jack Weeks flying Article 129 at 82,000ft. The area surveillance capability of the Type I camera is readily apparent, as is its resolution, enabling two helicopters to be both located and identified as large cargo-hauling Mil Mi-22 Hooks. (CIA via David Robarge)

Vojvodich recovered the aircraft back at Kadena after three instrument approaches in driving rain. The flight had lasted three hours and 40 minutes and, during an interview with this author, the pilot claimed that several SA-2s were fired at the aircraft but all detonated above and well behind the target. (This remains a matter of controversy to this day, for when the CIA's program manager for Oxcart, John Parangosky, wrote his classified paper about the project under the pseudonym Thomas P. McIninch, shortly after its termination, he asserted that no hostile action was taken against any of the first seven missions.) Notwithstanding, upon safe arrival back at the "barn" the film from the Type I camera was removed and flown by special courier aircraft to the Eastman Kodak plant in Rochester, New York, for processing. The processed imagery was then sent to Photo Interpreters at the National Photographic Interpretation Center (NPIC), located within the Washington Navy Yard, who then prepared the Initial Photographic Intelligence Report (IPIR). The results were astounding: in all, Article 131's camera had successfully photographed ten priority target categories including 70 of the 190 known SAM sites.

Jack Layton's first operational flight had to be aborted. All had gone well until he entered Deep Work, the refueling track just southwest of Okinawa, and plugged into the tanker's refueling boom. The boom operator's first remarks as the A-12's fuel tanks began to fill were, "You don't want to go





supersonic with this aircraft, Sir." The puzzled A-12 pilot enquired why, there being no cockpit indications that supported such a remark and the aircraft seemed to be handling well. "I don't think you'll want to go fast, Sir," the boom operator insisted, "because the left side of your aircraft is missing." After further consultation with the boom operator and other tanker crewmembers who went aft to view the unusual sight, Jack decided that prudence should dictate that he abort his first important mission – however reluctantly. As he turned back to Kadena, an F-102 interceptor was scrambled from Naha AB, Okinawa, to serve as escort back to "home-plate" in the event of controllability problems. As the Delta Dagger drew alongside the crippled Oxcart, the F-102 pilot reported that the A-12 had lost practically all of its left chine panels from nose to tail. In addition, large panels on the top of the wing (which also covered the top side of the wheel well) had also disappeared, allowing the chase pilot to see right through part of the aircraft's left wing. As some of these panels had broken loose, at least one had impacted the top of the left rudder, causing even more damage.

As the two aircraft descended below 20,000ft, they dipped into clouds and the A-12's cockpit fogged-up so badly that Jack was unable to see his hand in front of his face, let alone read his flight instruments. He quickly called for the F-102 pilot to report the A-12's attitude, since he was becoming very concerned that it might depart its flight envelope by stalling or diving. Relieved that he had remained within normal flight parameters, Jack managed to climb back out of the clouds. By turning the cockpit temperature control to full-hot, he managed to eliminate the humidity that had caused the fogging, but the hotter-than-normal cockpit soon became extremely uncomfortable. Nevertheless, he was able to safely recover back at Kadena without further incident.

During the first three months of Black Shield operations, nine missions were successfully completed. However, according to Parangosky, mission BX6705 flown by Jack Layton in Article 127 on June 20, 1967 was the first occasion that an Oxcart was successfully tracked on enemy radar. Bearing

This series of shots were all taken during mission BX6847 over North Korea and aptly demonstrate the amazing capabilities of the Type I camera – the very essence of what the A-12's mission was designed to generate. From 80,000ft, a film frame measuring 27in×6in captured a ground swath 72 miles wide. At nadir Hwangju Air Base was filmed; Photo Interpreters could then enlarge areas of interest many times to take a detailed look – in this instance, MiG-17s on the apron of the main runway. An SA-2 battery was filmed also close to nadir where together the camera and film produce a resolution of 1ft. Then, nearly 30 miles to one side of the Oxcart's track with a ground resolution of 2–3ft, is Yongbyon, North Korea's nuclear plant. (National Archives via Talent-Keyhole.com) in mind all the time and vast expense that had been invested in reducing the aircraft's RCS, this must have caused considerable consternation both back at CIA headquarters and within the Skunk Works.

By mid-July, Black Shield imagery had determined with a high degree of confidence that there were no surface-to-surface missiles in North Vietnam. But Oxcart flights were becoming invaluable, providing important intelligence to mission planners about the enemy's Order of Battle, as well as high-quality bomb-damage assessment imagery. The problem was the protracted timelines involved in processing the intelligence from film download, to receipt of the processed imagery and the IPIR.

To speed up the process, the 67th Reconnaissance Technical Squadron (Recce Tech), at Yokota AB, Japan, were also provided with the necessary skills and equipment to undertake the work. So following an enormous amount of hard work and dedication, on August 18, 1967, the 67th RTS was recertified as Overseas Processing and Interpretation Center – Asia (OPIC-A). This action provided theater commanders with Black Shield imagery and an IPIR within 24 hours of a mission. Subsequently, from BX6722, flown by Jack Weeks in Article 129 on September 16, 1967, this became the standard operating procedure throughout the remaining period of Black Shield.

From September to the end of December 1967, the three Black Shield-operated A-12s completed 11 operational missions – the highest period of activity being reached in October, when seven sorties were flown. Frank Murray's first operational mission, BX6727 (a so-called "double-looper"), was flown on October 6 in Article 131. His first photo-run at an altitude above 80,000ft on a track deep into North Vietnam went well. But as he was about to turn off his cameras before heading south toward Scope Pearl, the Oxcart air refueling track located over Thailand, his left engine started vibrating, followed shortly thereafter by a left inlet unstart. Frank recalled: "I had my hands full for a while. In fact, I ended up having to shut the engine down. I increased power on the good engine and flew it at maximum temperature for about an hour before I hooked up with the tanker. Because of the shut-down engine, I decided to divert into Takhli and the tanker crew relayed messages back to Kadena that I was diverting. Because I kept my radio calls to a minimum for security reasons, I didn't identify myself to the Takhli air traffic controllers until I was on final approach for landing. I landed without incident, but inadvertently screwed up a complete F-105 strike mission launch when I jettisoned the big brake 'chute on the main runway. I turned off the runway and sat there with the engine running and asked that the base commander come out to the aircraft as there were certain things I had to tell him. My presence was causing a pandemonium of curiosity; there was this most unusual black aircraft with no markings, the like of which nobody on that base had ever seen before, that had dropped in completely unannounced, disrupting a major operation and its pilot insisting on the base commander coming out to see him! While this was going on guys on base with cameras were clicking away like mad. Eventually they sent out the Thai base commander which was no good because I wanted the US base commander. He eventually arrived and (despite all my disruptions to his war operations) was extremely helpful."

After Frank's aircraft had been safely tucked away in an "Agency" U-2 facility on the base, the Air Force Security Police had a "field day" confiscating the opportunists' film. An inspection of the left engine revealed that most of its moving parts had been "shucked like corn from the cob" and were lying in the tail pipe and the afterburner. A recovery crew flew in with a spare engine, but

Article 131 had also sustained notable damage to the nacelle and to some of its nearby electrical wiring. It was decided that the jet would have to be flown back to Kadena AB "low and slow" on October 9. Frank explained: "I got airborne and headed off south over the Gulf of Thailand, where I picked up an F-105 escort that led me out over South Vietnam. There the escort was changed and the F-4s that had covered me and my tanker broke off to return to their base. We then made our way via the Philippines, where I picked up another tanker which led me back to Kadena."

Whilst Frank was dealing with the in-flight emergency over North Vietnam, his attention had been diverted away from switching off the photographic equipment to the more pressing priority of controlling the aircraft. As he turned south, his still-operating camera had taken a series of oblique shots into China. Close analysis of those photos revealed eight tarpaulin-covered objects among a mass of other material along the large main rail link between Hanoi and Nanking. Further photo interpretation ascertained that the "tarps" were flung over rail flatcars in an attempt to hide 152mm self-propelled heavy artillery pieces. A great mass of other war material in the rail yards had been assembled for onward movement to North Vietnam during the oncoming winter season when low clouds and poor visibility would hamper US bombing efforts to halt southbound supply lines. A timely and highly valuable piece of strategic intelligence, gained on the back of Frank's troubled sortie, had given intelligence specialists a unique opportunity to track the further movement of those guns and supplies, obviously intended for use in future offensive actions.

During sortie number BX6732, flown in Article 131 by Denny Sullivan on October 28, 1967, the pilot received indications on his RHAW receiver display of almost continuous radar activity focused on his A-12, whilst both inbound and outbound over North Vietnam. This culminated in the launch of a single SA-2 – according to Parangosky, the first ever at an Oxcart. Two days later, during the course of sortie BX6734, Sullivan was flying Article 129 high over North Vietnam when on the first eastbound pass, between Haiphong and Hanoi, his RHAW receiver display indicated that two SA-2 sites were tracking him and preparing to engage the Oxcart; but neither launched. However, during the second pass, whilst heading west and in the same area as earlier, at least six missiles were fired from sites around the capital. Looking through

Denny Sullivan has the questionable distinction of being the only Oxcart pilot to have definitely been attacked twice by SA-2s, during separate Black Shield missions – BX6732 and BX6734. (CIA) his rear-view periscope, Sullivan reported seeing six vapour trails climb to an estimated 90,000ft behind the aircraft and then arc toward it. He reported observing four missiles, one as close as 100–200yds away (when flying at speeds of one mile every 1.8 seconds, that really is extremely close), and three detonations, all behind the aircraft – six missile contrails were captured on the Type I camera's film. After recovering the aircraft back at Kadena without further incident, a post-flight inspection revealed that a tiny piece of shrapnel had penetrated the lower wing fillet of his aircraft and become lodged against the support structure of the wing tank – history would prove this to be the only enemy "damage" ever inflicted on a "Blackbird."

The North's missile activity caused DCI Richard Helms to order the temporary suspension of all Black Shield flights, during which time those involved were given the opportunity to review and re-evaluate procedures and routes. In fact, it was more than a month before operational flights resumed and their reintroduction saw a temporary switch of target areas – for the first time, the "collection area" was Cambodia. Black Shield missions BX6737 and 6738 both utilized Article 131 and were flown by Mele Vojvodich on December 8, 1967 and by Jack Layton two days later. However, during the first four-hour sortie, cloud cover obscured four of the seven special search areas for troop concentrations in the extreme northeast part of Cambodia, including both primary targets – although limited troop activity was detected where the Tonle San River crosses the Cambodia/Laos border, together with the regrading of the natural-surface runway at Ban Pania Airfield. In contrast, the virtually cloud-free conditions experienced by Jack Layton on December 10 enabled his Type I camera to gather valuable photography on all seven priority search areas – although this was secured not without issue. As Jack recalled, the INS caused the aircraft to overshoot the planned track during turns, causing him to "penetrate the bamboo curtain." After turning south and getting back to an approximate course toward Scope Pearl, the air refueling track over Thailand, he had difficulty finding the tankers due to low cloud and poor visibility: "I got the aircraft up in a bank to search for the tankers but the visibility from an A-12 is very poor; you can look down and see the ground but you can't look inside the turn because of the canopy roof. I'd just about reached the point where I was about to divert to Takhli due to the lack of fuel when I finally saw the tankers. We got together and I was able to complete the mission even though the INS wasn't working."

On December 15 and 16, overflights of North Vietnam resumed. To limit exposure to the SA-2 risk, mission planners re-orientated the route, moving the track from an east/west direction to a less productive south/north route. The next two missions, BX6739 and 6740, both adhered to the amended route and no SA-2s were fired. However, when Jack Layton flew BX6842, reverting back to the earlier east/west route, on January 4, 1968, he was attacked by a single

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CLOSE SHAVE

Having been fired upon by a single SA-2 Guideline SAM on 28 October 1967, Denis Sullivan had the very dubious privilege of being attacked by a salvo of missiles just two days later. Sullivan was maintaining an easterly heading in the vicinity of Hanoi at the time of the attack. The Type I camera carried by his Oxcart captured no fewer than six SA-2 contrails on film and post-flight inspection revealed that a tiny piece of shrapnel had actually penetrated the aircraft's lower wing fillet, and become lodged against a support strut of the wing tank. This "close shave" would prove to be the nearest that any "Blackbird" would ever come to being shot down throughout its entire operating career.

Details including latitude, longitude, time (GMT), and ground speed were applied to each photo frame via the data chamber. This enabled Photo Interpreters to establish the exact position of targets captured by the Type I camera. Note that this frame was taken during Black Shield mission BX6847; the coordinates are those of Wonsan Harbor, North Korea. The ground speed displayed only three digits – the thousandth column was omitted as this was considered "a given!" (National Archives via Talent-Keyhole.com)

SA-2, again during the second pass. On this occasion, the missile was launched with its Fan Song missile control radar in low PRF – a highly significant event, being the first known instance of a Soviet SA-2 having been guided by information derived from the Fan Song operating in low PRF mode. The aircraft's ECM equipment – Mad Moth and Blue Dog – was activated and the missile missed its intended target.

As 1967 drew to a close, a total of 41 Black Shield missions had been alerted by project headquarters, of which 22 were actually flown. Between January 1 and March 31, 1968, 17 missions were alerted, of which seven were flown: four over North Vietnam and three over North Korea. The main reason why scheduled flights were subsequently scrubbed was invariably poor weather conditions in the collection area.

North Korea

In a CIA document classified Top Secret, the rationale was outlined for Oxcart reconnaissance missions against North Korea. It stated that the belligerent pronouncements by North Korean civil and military leaders and an increase in the number and expanded scope of North Korean probes along the DMZ, coupled with their efforts to establish the structure for guerrilla operations in the Republic, had established a critical requirement for accurate intelligence. It further noted that satellite photo missions had not provided adequate imagery of North Korea to satisfy the requirement and that ground collection of this intelligence was becoming increasingly difficult. Taken together, this had made an accurate estimate of capabilities and intentions all but impossible. It continued that the operational concept could now be accomplished on a 24-hour alert basis, using Oxcart operational Black Shield assets in place at Kadena AB, without coverage degradation of targets in North Vietnam. Three passes traversing the target areas, east to west or west to east, could be accomplished utilizing two air refuelings, or two passes of similar orientation could be executed with a single air refueling. In a footnote at the bottom of an attached sample route map, it added that photographic resolution would be in the order of 1–3½ft and that two eastbound and one westbound pass over the north would take a total of just 17 minutes to complete. Despite this, the US State Department vetoed the plan – but this was about to change.

The *Pueblo* affair

On January 5, 1968, US Navy Auxiliary General Environmental Research Ship number 2 (AGER-2), USS *Pueblo*, proceeded as ordered unprotected, on its maiden voyage to "sample the electronic environment off the east coast of North Korea." On board were a crew of six officers, two civilians, and 75 enlisted men. Just 18 days later during the night of January 23, the ship's radio operator managed to get off an emergency signal. "We Need Help! We Are Holding Emergency Destruction! We Need Support! SOS. SOS. SOS. Please Send Assistance! SOS. SOS. SOS. We Are Being Boarded!' The last sentence clearly stated what was happening aboard the beleaguered vessel, and with one sailor dead and the rest of the crew captured, the year-long nightmare for Lt Cdr Lloyd M. Bucher and his crew was just beginning.

In response to this potentially explosive international incident, President Johnson summoned his top advisors to a meeting at the White House the very next day (January 24) to plan a response and agree a course of action. Later that same day, DCI Richard Helms dispatched a top-secret memo to Walt Rostow, Special Assistant to the President; Secretary of Defense Robert McNamara; Under Secretary of State Nicholas Katzenbach; Deputy Secretary of Defense Paul Nitze, and Chairman of the JCS, Gen Earle Wheeler, in which he referred to the earlier meeting and confirmed that he was "alerting an Oxcart mission for photo reconnaissance of North Korea." It continued: "The Oxcart mission has been alerted to take off [deleted] on 25th January at 2100 EST (1100 / 26 January [delete]) and return four and a half hours later. The film will be off loaded immediately and airlifted to Eastman Kodak, Rochester, New York, to arrive at approximately 0430 EST on 27 January. The processed film will be delivered immediately to NPIC with an arrival time of 1440 EST on 28 January." Point 3 in the memo noted, "The weather forecast for this mission indicates Category II (25 percent or less cloud cover) weather conditions for the target area." Finally point 4 noted, "No additional resources or support over and above those normally used on Oxcart North Vietnam operational sorties will be required for this mission."

The draft CIA plan to overfly North Korea was about to be implemented in full; in all, three A-12 sorties would be flown as a consequence of the capture of USS *Pueblo*. The first of the three sorties was BX6847, flown on January 26, 1968, by Jack Weeks in Article 131 – just 24 hours after the ship was captured. The Oxcart was equipped with Pin Peg, Mad Moth, Blue Dog II ECM defense suite, System IV ELINT recorder, and a Type I camera. USS *Pueblo* was located at anchor some distance from Wonsan Bay, and despite a right engine inlet unstart on the third pass, Jack's four-hour sortie was a spectacular success – helped by the fact that 90 percent of North Korea was cloud-free. A declassified critique of the mission noted that 71 of 84 programed targets were imaged, together with one

Jack Weeks was the first Oxcart pilot to be sent over North Korea to try to locate the hapless USS *Pueblo*, a mission his Type I camera system accomplished during BX6847 on January 26, 1968. (National Archives via Talent-Keyhole.com) surface-to-surface missile target, 81 of the 126 Committee on Imagery Requirements and Exploitation (COMIREX) targets, plus 13 SAM sites – of which 12 were occupied – and 752 bonus targets. The report concluded that BX6847 "obtained good baseline coverage of most of North Korea's armed forces, as well as large portions of the transportation system and industrial base" – testament indeed to the platform's outstanding capabilities.

Despite the undisputed success of BX6847, US State Department officials were extremely wary of endorsing a second mission over North Korea after the *Pueblo* incident. The diplomatic scars left by the 1960 U-2/Powers shoot-down were still sensitive eight years later. It wasn't until Brig Gen Paul Baclais (Director of the OSA) had briefed Secretary of State Dean Rusk on the specific mission objectives and assured him that the aircraft would only be in North Korean airspace for seven minutes (two passes or "photo lines") that the State Department gave its blessing and the three-hour 39-minute sortie, designated BX6853, was flown in Article 127 by Frank Murray on February 19, 1968. Equipped with the same sensors as the previous incursion, 88 percent of the programed targets were cloud-free; however, this proved not to be the case where USS *Pueblo* was concerned, and she remained hidden from 127's prying Type I camera.

On May 6, 1968, Jack Layton launched Article 127 on sortie BX6858 and headed out on Oxcart's third mission to North Korea. Unknown to him at the time, his mission proved to be the final operational flight of the entire A-12 program. The reconnaissance "take" was disappointing in comparison to the two earlier missions as 50 percent of the programed targets suffered degradation due to cloud and haze. Then on the high-speed flight back to Kadena AB, "milky white fingers" began slowly clawing their way across the front of the left windshield panel. Having already experienced this "white-out" phenomenon to a lesser degree during a stateside training sortie, Jack was aware of the problem, which was caused by frictional heating on the windshield to the point that the glue between glass laminations became viscous and turned completely opaque. Proceeding on instruments all the way to landing, Jack completed a successful ground-directed radar approach for a safe recovery back at Kadena AB after three hours and 30 minutes in the air.

Although the procurement of such intelligence information was not of direct benefit to Lt Cdr Bucher and his crew, who were beaten and not released by their North Korean captors until nearly a year had passed, such a "hot-spot, quick-look" capability was considered an early and important achievement of the Oxcart program, clearly demonstrating the validity of manned reconnaissance vehicles and their ability to respond with minimal lead times to international incidents of political and military importance. At the same time, the *Pueblo* incident signaled the end of the Navy's seaborne foray into the world of SIGINT trawling, the two remaining AGERs being scrapped soon after USS *Pueblo*'s seizure.

F

PARTING SHOT

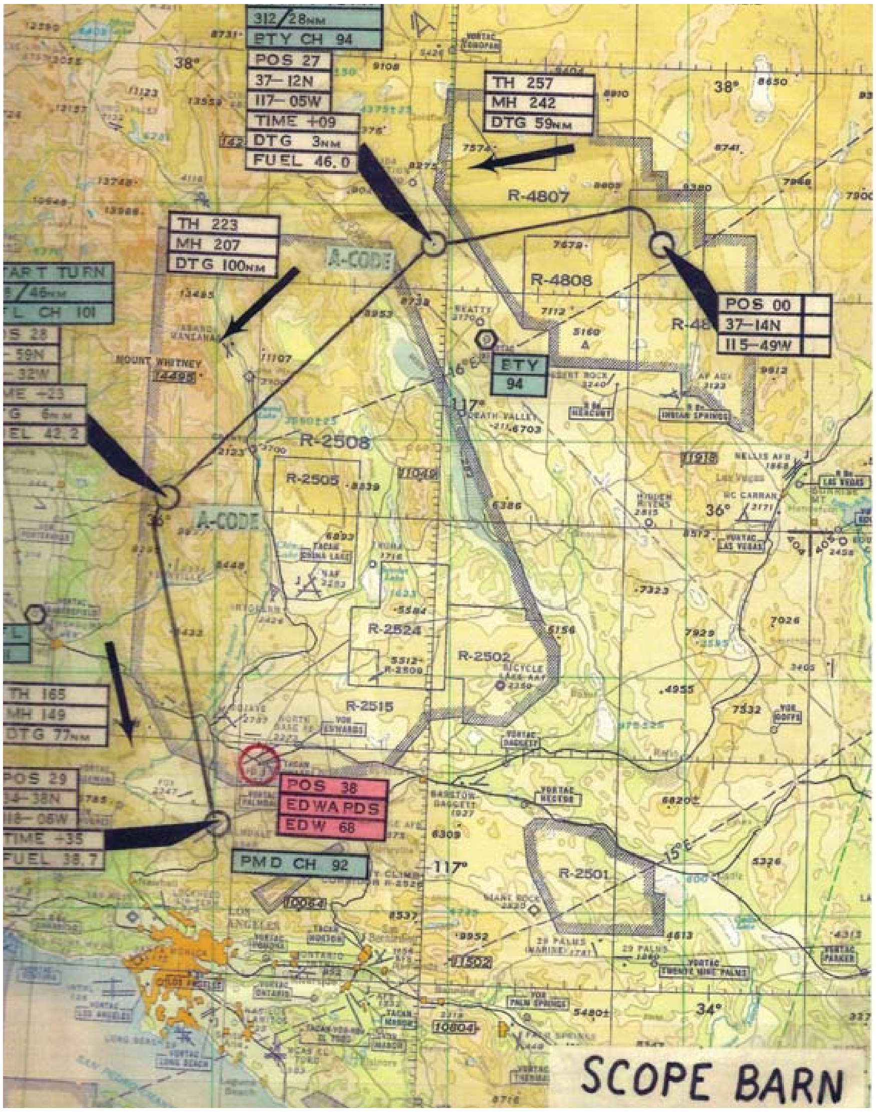
During the first mission following the resumption of Black Shield sorties on their earlier east–west, west–east tracks over Hanoi, Jack Layton was fired upon by a single SA-2 whilst flying Article 127 (serial 60-2930), on 4 January 1968. The missile was fired while its Fan Song guidance radar was operating in low PRF (Pulse Recurrence Frequency) mode. The missile missed its intended target and according to CIA records, this was the last occasion that an Oxcart was fired upon during its operational career.

Article 129 (60-6932) completed five Black Shield missions and was the last Oxcart to be lost in an accident. Cruelly, it occurred on June 5, 1968 – after the program had officially been canceled – and claimed the life of the pilot, Jack Weeks. (CIA)

Oxcart closedown

It seems almost unbelievable that during the very month Oxcart was finally declared operational (November 1965), and before the program had the opportunity of fully vindicating itself, moves were already afoot to close it down. The Bureau of the Budget (BoB) questioned the necessity and cost of funding both the covert CIA Oxcart A-12 program and the "overt" USAF Senior Crown SR-71 program. Its author proposed several less costly alternatives, recommending that the A-12s be phased out by September 1966 and that all further procurement of SR-71s should stop. Copies of the memorandum were circulated within limited circles of the Defense Department and the CIA, together with the suggestion that they explore the alternatives set out in the paper. Since the SR-71 was not scheduled to become operational until September 1966, the Secretary of Defense quite rightly declined to accept the proposal. In July 1966, BoB officials proposed that a tri-agency study group be set up to again establish ways of reducing costs of the two programs. After the study was completed, a meeting was convened on December 12, 1966, and a vote was taken during which three out of the four votes cast were in favor of terminating the Oxcart fleet in January 1968 (assuming an operational readiness date of September 1967 for the SR-71) and assigning all missions to the SR-71 fleet.

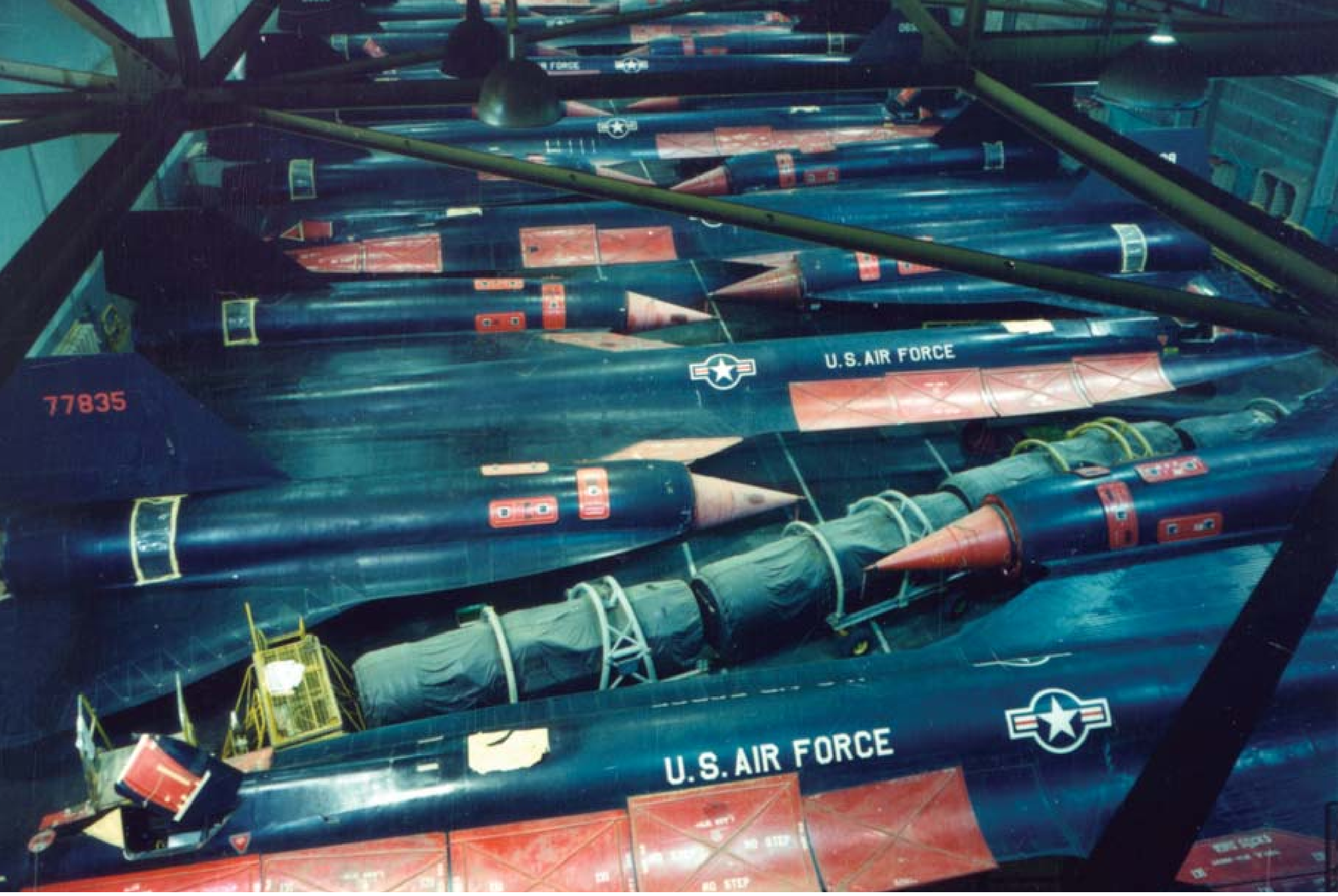
The BoB's memorandum was transmitted to President Johnson on December 16 despite protestations from the DCI, Richard Helms, who was the sole dissenting voice in the vote. Twelve days later Johnson accepted the BoB's recommendations and directed that the Oxcart program be terminated by January 1, 1968. However, as the Vietnam War escalated and the results of Black Shield's outstanding work became apparent to a privileged few, the wisdom of the earlier phase-out decision was called into question. As a result, the rundown lagged and the issue was again addressed. On November 3, 1967, the two competing aircraft types and their respective reconnaissance-gathering



Scope Barn: the return of Oxcarts to Lockheed's facility at Palmdale in California following program shutdown. This is a copy of the actual chart used by Frank Murray to position the last remaining A-12 from Area 51 to Palmdale. (Roadrunners Internationale)

sensors were pitted against one another in a stateside fly-off codenamed Nice Girl. The outcome was deemed inconclusive, although the resolution of the A-12's Type I camera was better than the optics of the SR-71. However, SR-71 had the ability to gather simultaneous, synoptic coverage of a target area that not only included PHOTINT and SIGINT, but more importantly, RADINT, via its nose-mounted, ground-mapping radar antenna. Despite continued objections raised by Helms, the original decision to terminate Oxcart was reaffirmed on May 16, 1968 by the Secretary of Defense – a decision further endorsed five days later by President Johnson.

Project officials decided that June 8, 1968 would be the earliest date to begin the redeployment from Kadena AB back to the United States. During the intervening period, sorties would be restricted to those essential for maintaining flight safety and pilot proficiency. Meanwhile, those aircraft back at Area 51 were to be flown to Lockheed's facility at Palmdale in California and placed in storage by June 7. Back at Kadena, preparations were being made for Oxcart ferry flights back to the United States. Mission sensors were



Following program shutdown, the remaining M-21 and eight A-12s were placed in long-term storage in a hangar at Palmdale, California. Note the bogus serial number in red that had been applied to Article 131, serial 60-6937, during Operation Black Shield. The "US Air Force" titles and the star-and-bar national insignia were additions to Article 131 subsequent to the project being terminated. (Lockheed Martin)

downloaded, low-time/high-performance engines were replaced with less highly-tuned units, and Functional Check Flights (FCFs) were flown to confirm each aircraft's readiness for the trans-Pacific ferry flights.

On June 4, 1968, Jack Weeks left Kadena in Article 129, with the intention of conducting an FCF; he completed a 34,000lb fuel on-load from the tanker, accelerated, and climbed away, and that was the last anyone ever saw of both pilot and aircraft. Forty-two minutes into the flight, the Birdwatcher-sensor system on the A-12 transmitted a signal to Kadena AB, indicating that the starboard engine EGT was in excess of 860 degrees C. Twenty-two seconds later, Birdwatcher indicated that fuel flow to the same engine was less than 7,500lb per hour. Just eight seconds on and a third and final transmission from Article 129's Birdwatcher repeated the earlier information; this time, however, it ominously included data indicating that the aircraft was now at or below 68,500ft. From this limited evidence, it is reasonable to conclude that some kind of malfunction involving an over-temperature and low fuel flow on the right engine had somehow contributed to what appears to have been a catastrophic failure and subsequent aircraft break-up. Not a trace of wreckage was ever found and it was particularly ironic and an especially cruel twist of fate to lose such a highly competent and professional pilot on one of the very last flights of the Oxcart program.

During early June 1968, the two remaining Black Shield A-12s at Kadeana AB (Articles 127 and 131) were ferried back to Area 51 before being positioned to Palmdale. On reaching the Lockheed plant, company maintenance technicians drained all fuel and hydraulic lines, and Mel Rushing skillfully "interwove" all nine remaining Oxcart aircraft into a tightly regimented, sardine-like parking array in a corner of one of the large hangars, where they remained for more than 20 years before being dispersed to museums.

On June 26, 1968, Deputy Director of the CIA, Vice Adm Rufus Taylor, presided over a ceremony at Area 51 where he presented the CIA Intelligence Star for Valor to Ken Collins, Jack Layton, Frank Murray, Denny Sullivan, and Mele Vojvodich for their participation in Black Shield; the posthumous award to Jack Weeks was accepted by his widow. The Legion of Merit was presented to Col Slip Slater and to his deputy, Col Amundson. In addition, the Air Force Outstanding Unit Award was presented to members of the Oxcart Detachment, the 1129th Special Activities Squadron, also known as "The Road Runners."

The long-standing debate as to whether Oxcart, or a program known as Senior Crown, should carry forward the manned strategic reconnaissance baton, had been resolved: the single-seat A-12 was vanquished; the new kid on the block was to be the Air Force two-seat SR-71A. In early March 1968, SR-71As began arriving at Kadena AB to take over the Black Shield commitment.

NASA operations

In 1967, a deal was struck between NASA and the Air Force whereby the former was given access to early A-12 wind tunnel data in exchange for NASA providing a small team of skilled engineers to work on the SR-71 flight-test program. NASA signed a memorandum of understanding with the Air Force on June 5, 1969, which permitted them access to the two remaining YF-12As then in storage. Phase one of the program was controlled throughout

A T-38 chase plane accompanies a YF-12A whilst serving with NASA. The YF-12A has an instrumentation package below the fuselage for a series of so-called "cold wall" experiments. (NASA)

by the Air Force and got underway at Edwards AFB on December 11, 1969, utilizing YF-12A 60-6936. Essentially this phase consisted of developing possible bomber penetration tactics against an interceptor with the YF-12's capabilities. It terminated on June 24, 1971, after the aircraft caught fire during the closing stages of the 63rd flight, whilst on base-leg at Edwards AFB. Fortunately both crewmembers safely ejected, but the aircraft crashed and was totally destroyed.

Whilst the YF-12As were being readied for flight two, NASA crews were checked-out by senior Air Force SR-71 crewmembers. Utilization of the high-speed platform proved to be high, since NASA engineers at Langley were interested in aerodynamic experiments and testing advanced structures; Lewis Research Establishment wanted to study propulsion, whilst Ames Research Center concentrated on inlet aerodynamics and the correlation of wind-tunnel and flight-test data. In addition, the aircraft was used to support various specialized experimentation packages.

Ultimately, 60-6935 continued operating until the program ceased after its 145th NASA flight on October 31, 1979. A week later an Air Force crew ferried the aircraft to the Air Force Museum (now the National Museum of the US Air Force) at Dayton, Ohio, where it is displayed as the sole surviving example of the YF-12A.

CONCLUSION

The failure to produce wide-band suppression of the U-2's RCS during phase one of Project Rainbow – as required by President Eisenhower – generated the need to design and build a totally new replacement aircraft. It would be interesting to speculate what an eventual U-2 replacement aircraft would have looked like if the RCS conundrum had been solved back in the late 1950s!

Project Oxcart's contribution should therefore be evaluated from two perspectives, namely execution of the strategic reconnaissance-gathering mission whilst operated by the CIA and as an aviation accomplishment.

As a strategic reconnaissance-gathering platform, Oxcart's overall contribution to the CIA's intelligence database was probably negligible compared to that made by other assets, such as the U-2 and satellites. However, this is not a fault of the aircraft per se, since it was US policymakers that decided not to employ the aircraft in the role for which it had originally been designed. The simple fact of the matter is that manned overflight of the Soviet Union following the May 1, 1960 U-2 shoot-down became politically unacceptable, so to a degree Oxcart became "an advanced anachronism."

Some commentators have made operational cost comparisons between Oxcart and the U-2, but this is disingenuous. Yes, the U-2 was much cheaper to operate; however, as demonstrated over both the USSR and Cuba, the U-2 was vulnerable to interception by SA-2s and was therefore incapable of executing its mission in such an environment. This was not the case with Oxcart, as proven during Black Shield – it was able to complete its mission despite the presence of SA-2s.

Frank Murray (right) is pictured here receiving the coveted CIA Star for Valor, with his wife Stella and Adm Rufus Taylor (Deputy Director of the CIA). The presentation took place in Col "Slip" Slater's conference room of the Headquarters building at Area 51. (Roadrunners Internationale)

During Black Shield, Oxcart provided US decision-makers with high-resolution, area PHOTINT coverage, proving there were no surface-to-surface missiles in North Vietnam. Its coverage of North Korea demonstrated that they were not planning some form of follow-up military action after seizing USS *Pueblo*. Black Shield also acquired timely invaluable PHOTINT of North Vietnam's air defense network, and other war-related targets, enabling US military commanders to plan more effective bombing routes, which inevitably resulted in US lives being saved. But in so doing it could be argued that Oxcart was in effect being used as a tactical collection platform in a conventional military conflict – an activity that fell completely outside the CIA's modus operandi.

However, when it comes to evaluating the A-12 or for that matter the YF-12 or latterly, the SR-71 in terms of aerospace design and performance accomplishments, the "Blackbird" family are without equal. More than 50 years after the first A-12 flight, they remain the fastest, highest-flying jet-powered aircraft ever built. Clarence "Kelly" Johnson and his team of Skunk Works aerodynamicists, thermodynamicists, electrical engineers, and physicists produced unrivaled innovations in aerodynamic design and metallurgy; and when it came to RCS suppression, they helped define the very foundations upon which future stealth research was based. Pratt & Whitney produced the unique, bleed bypass engine, whilst the Perkin-Elmer's Type I camera produced image resolution of previously unheard of clarity.

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DEDICATION

To Frank Murray and T.D. Barnes

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