Stealth Warplanes



BILL GUNSTON

With full colour artworks and photographs

COMBAT AIRCRAFT SERIES

Stealth Warplanes

BILL GUNSTON

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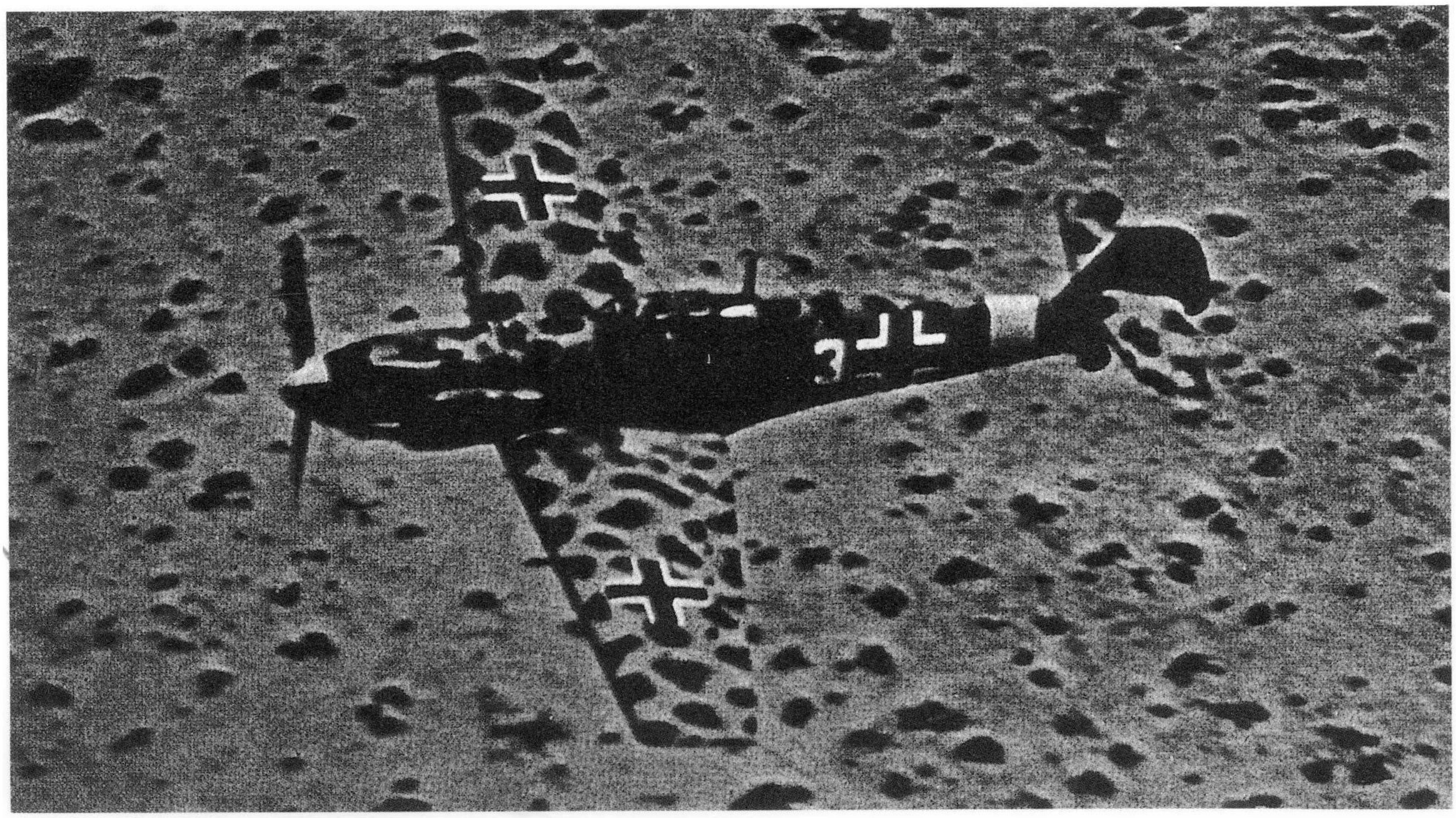
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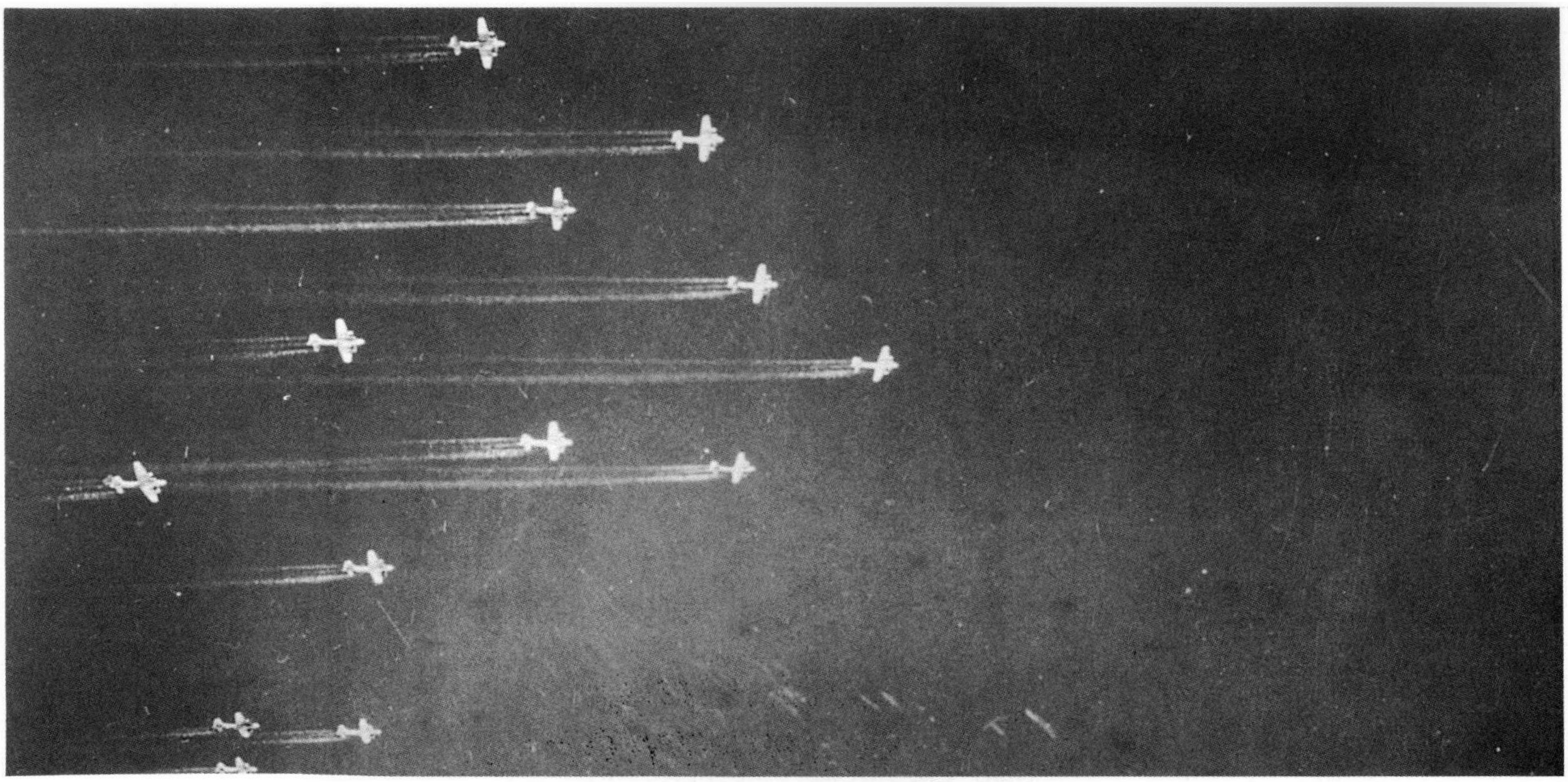
UNTIL THE BOER WAR, at the start of the 20th Century, soldiers of the British Army wore bright red tunics. The Boer snipers could pick them off from great distances. Soon afterwards the vivid red was changed to khaki, and since then a lot of thought has gone into trying to camouflage army troops and vehicles to make them as inconspicuous as possible.

A few years later, in 1911–15, aeroplanes began to play a part in human conflict. The first aeroplanes of the Allies to fly over the Western Front in 1914 found that they were being fired upon by their own troops. The answer seemed to be to proclaim their identity, so British machines were painted with huge Union Jacks, while the French devised the "roundel" of red, white and blue. Later the British also adopted the roundel, but with colours in the reverse order. Ever since, "legitimate" warplanes have carried an internationally understood marking of national identity.

Throughout the rest of World War 1 most warplanes were painted with cellulose dopes which both protected the fabric and also made the aircraft difficult to see. British machines were usually various shades of khaki, but heavy German bombers used an amazing pattern of multicoloured hexagons. In sharpest contrast, the crack fighter units of the German air force deliberately encouraged each pilot to paint his aircraft as conspicuously as possible. Probably the best-known example was the all-scarlet Dr.I triplane of "The Red Baron", but other Fokker and Albatros scouts had every possible arrangement of gaudy colours, all calculated to gain a psychological advantage over the enemy.

Below: Painted camouflage sometimes appears to work well. This Messerschmitt Bf 109E-4/Trop of Luftwaffe staffel I/ JG27 was photographed flying over what is today Libya in 1941. The white band indicated the Mediterranean theatre.





Above: Boeing B-17G bombers of the US Army 8th Air Force high over Germany in 1944. Contrailing formations like this were often 50 miles (80km) long, and concealment was hardly relevant. The bombers were left unpainted.

Thus, actual warfare resulted in some aircraft being made deliberately conspicuous, while the majority tried to merge into the background. Indeed a few even tried to become invisible! As early as spring 1912 a Taube monoplane of the Austro-Hungarian forces was covered not with normal woven fabric but in material resembling Cellophane in an endeavour to make it transparent. Observers said it was almost impossible to see even when flying at quite low altitudes. Subsequently dozens of aeroplanes—one Russian, the rest German—were covered wholly or partly in transparent film, usually called Cellon. There were many drawbacks, apart from the obvious one that transparency could not extend to the crew, engine, tankage, wheels, armament and other parts.

Another "transparent" machine was built in the Soviet Union in the early 1930s, but all other warplanes right up to the 1970s have either ignored the problem of how to remain undected by the enemy or used conventional dopes to achieve an effect thought to merge into the background, especially when seen from above. Of course, the ideal aircraft would be able to emulate the chameleon and change colour at will, but the nearest anyone got to this was to apply a crude all-white finish with the first snow of winter, scrubbing it off again next spring.

Nobody bothered overmuch about trying to cut down aircraft noise or heat (IR, infra-red) emission, though they did try to make flight crews preserve radio silence wherever possible. Early British attempts to bomb Germany in daylight were so costly that almost all later attacks were made at night, which automatically provides a form of camouflage all of its own. But by this time human eyes had been supplemented by the invention of radar, and this soon made traditional camouflage less important. It also led to the new science of ECM (electronic countermeasures) in which one side tries to blind or mislead the radars of the other. Meanwhile, huge forces of US bombers ranged over hostile territory, in daylight often creating vapour trails, and camouflage became so superfluous it was soon omitted, leaving aircraft in gleaming aluminium and often with bright markings.

Today there will be no more giant armadas. Most combat missions will be flown by single aircraft, and in order to survive in what has become a perilous sky they will do everything in their power to remain undetected. This means that modern military aircraft must be of "stealth" design, using "low observables" technology. They must be silent, difficult to see by eyes, difficult to see by radar and undetectable by sensitive IR (heat) sensors. At present nobody knows how to create a true stealth aircraft, but this book describes how far we have already come.

2

Unseen by eye

PASSAGE OVERHEAD OF THE "transparent" aircraft modified during WW1 must have been eerie, rather like seeing not a normal man or animal but just the skeleton. Contemporary accounts were often enthusiastic. The magazine *Flight* reported in 1914 "Only the framework is dimly visible, and this and the outline of the motor and pilot and passengers present so small an area for rifle or gun fire that, at the rate of speed at which aeroplanes are flown today, accurate aiming at such surfaces becomes nearly impossible".

Exciting maybe, but the objective of true stealth design—of preventing enemies from knowing of the aircraft's presence—was not even attempted. The author knows of no effort to make a transparent aircraft that was also silenced. Had this been done the result might have been more interesting, because this was before the era of detectors able to operate at EM (electromagnetic) wavelengths other than those of visible light, such as radio waves (radar) and heat (IR).

In any case, there were problems with the transparent films. They were quite strong, but if they got wet they became loose and floppy, causing a large reduction in wing lift and a large increase in drag. When seen obliquely the sheet became less transpa-

Below: In close proximity to enemy ground forces the A-10A needs all the help it can get. During JAWS (Joint Attack Weapon System) trials this aircraft was repainted daily to match the topography and prevailing weather conditions.





Above: From most aspects the F-16 has quite a small RCS, and it also introduced pale grey radomes. None of this is of much consequence if it goes into full afterburner and streams condensation vapour behind its wing roots, as here.

rent, and it often reflected sunlight brilliantly, which not only made the aircraft highly conspicuous but could blind the crew. Peppering with shell splinters could cause the whole film to disintegrate, and the film was also appreciably heavier than normal fabric. Suffice to add that in today's era of highly stressed skins made of special alloys and fabulously strong composites, nobody would even consider embarking on a project to try to make a combat aircraft transparent. The idea is fascinating and tempting, but even if complete success were attained (invisible jet engines, pilot, ejection seat, systems, avionics, bombs . . . ?) it would solve only one of the four big challenges of stealth design. These challenges are covered in subsequent chapters.

So, lacking the ability to make the invisible warplane, the world's air staffs and designers have had to fall back on paint, very much a second best answer. It is, of course, possible to paint an aircraft so that it appears almost invisible when seen against a particular background, but as far as the author knows, no laboratory has yet even begun to commit major funds to trying to solve the problem of creating chameleon-like coatings. In the longer term this may become possible, but at present the manufacturers of aircraft finishes would say they have quite enough to do meeting the harsh specifications for colour-fastness, ability to withstand intense cold (at high altitudes, for example), and above all to resist the impact of supersonic dust particles, sand and grit, birds, rain and (worst of all) hailstones.

Today any paint finish, be it "low-viz" or very bright, is rendered largely superfluous because radars have become much cleverer, IR detectors are said to be sensitive enough to "lock on to a lighted cigarette at a range of half a kilometre", and in any case most warplanes blast out flaming jets, make a thunderous din and not infrequently leave sooty trails. Today we know better, and realize that to survive in defended airspace future aircraft must be as nearly as possible of stealth design.

Where detection at optical wavelengths is concerned, it first of all means there must be no visible trail whatsoever from the engine(s). Unfortunately, in certain conditions of humidity the vortex streaming behind the wingtips or other parts of an aircraft can cause almost instantaneous condensation, leaving a vivid whitish trail which often has a visible writhing motion; this is often seen behind the wing-root strake extensions of most modern fighters. If the aircraft were to be truly invisible such a trail would not be terribly obvious, but stealth aircraft are deliberately designed not to form such vortices in any normal flight condition.

A further obviously crucial requirement is that sunlight (or even moonlight) should never glint from polished reflective surfaces. The obvious such surfaces are the canopy and windscreen, but even a

smooth polished wing or other surface could be highly reflective. In the past matt (non-reflective) surfaces tended to thicken the boundary layer of air dragged along in close proximity to the aircraft, and thus caused higher drag. Today much research is in hand to try to make sprayed coatings that are totally non-reflective (of various kinds of EM radiation, including visible light and radio waves) and also have little or no effect on flight performance.

The problem is greatly complicated by the design of modern combat aircraft. Only about half their area of external surface, the so-called "wetted area" of the aerodynamicist, is made up of ordinary skin. The rest is made up of doors, hatches, suppressed antennas (aerials), canopies and windscreens, radomes, special sensors and other avionic devices, projecting afterburner nozzles, multiple external stores racks and other devices, to say nothing of the external stores themselves.

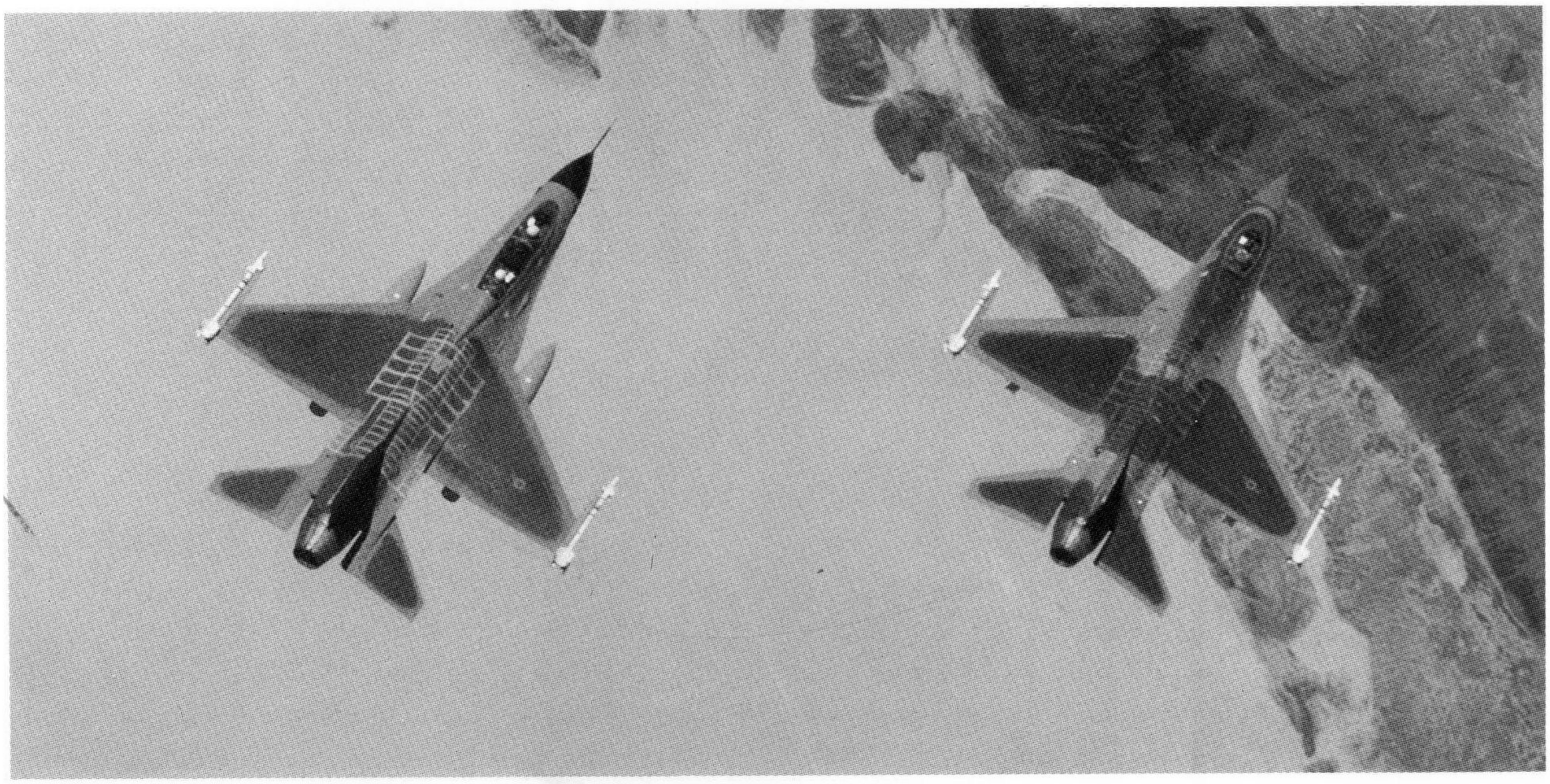
Insignia and camouflage

Legally it is a requirement to display national insignia (though there is no internationally agreed distance at which this has to be recognizable) and to avoid dazzling the pilot there is often non-reflective black ahead of the windscreen and sometimes on other parts near the cockpit. Until recently radomes and most other coverings over suppressed or projecting avionics antennas had to be made of particular kinds of non-conductive dielectric material, and could not be painted. Today, however, this problem is being overcome. The General Dynamics F-16 was one of the first aircraft which, starting out with a normal black nose radome, later received one painted the same grey colour as the rest of the aircraft.

The F-16 typifies those air-combat fighters which in bygone years might have gone into battle proudly painted in the most conspicuous colours possible, but which today follow the path of prudence and not only have an overall finish of low-observability grey shades but also display the national insignia, unit code letters and aircraft serial number in low-contrast grey or white.

Where we are going is slightly uncertain. The Lockheed SR-71 Blackbird and TR-1A are a uniform black all over (the colour is sometimes, misleadingly, asserted to be a very dark blue). This is because "iron ball paint" happens to be this colour, and when flying 15 miles (24km) above the Earth the colour scheme is probably of secondary importance. Future stealth aircraft, whose missions are flown chiefly at low level, will have to reconcile the conflicting needs of RAM (radar-absorbent material) coatings with the requirement to try to be optically invisible.

Below: An F-16B (left) and F-16A flying over Nevada during early tests of low-visibility paint schemes. White Sidewinders, bonedomes and the F-16B's black radome are conspicuous.



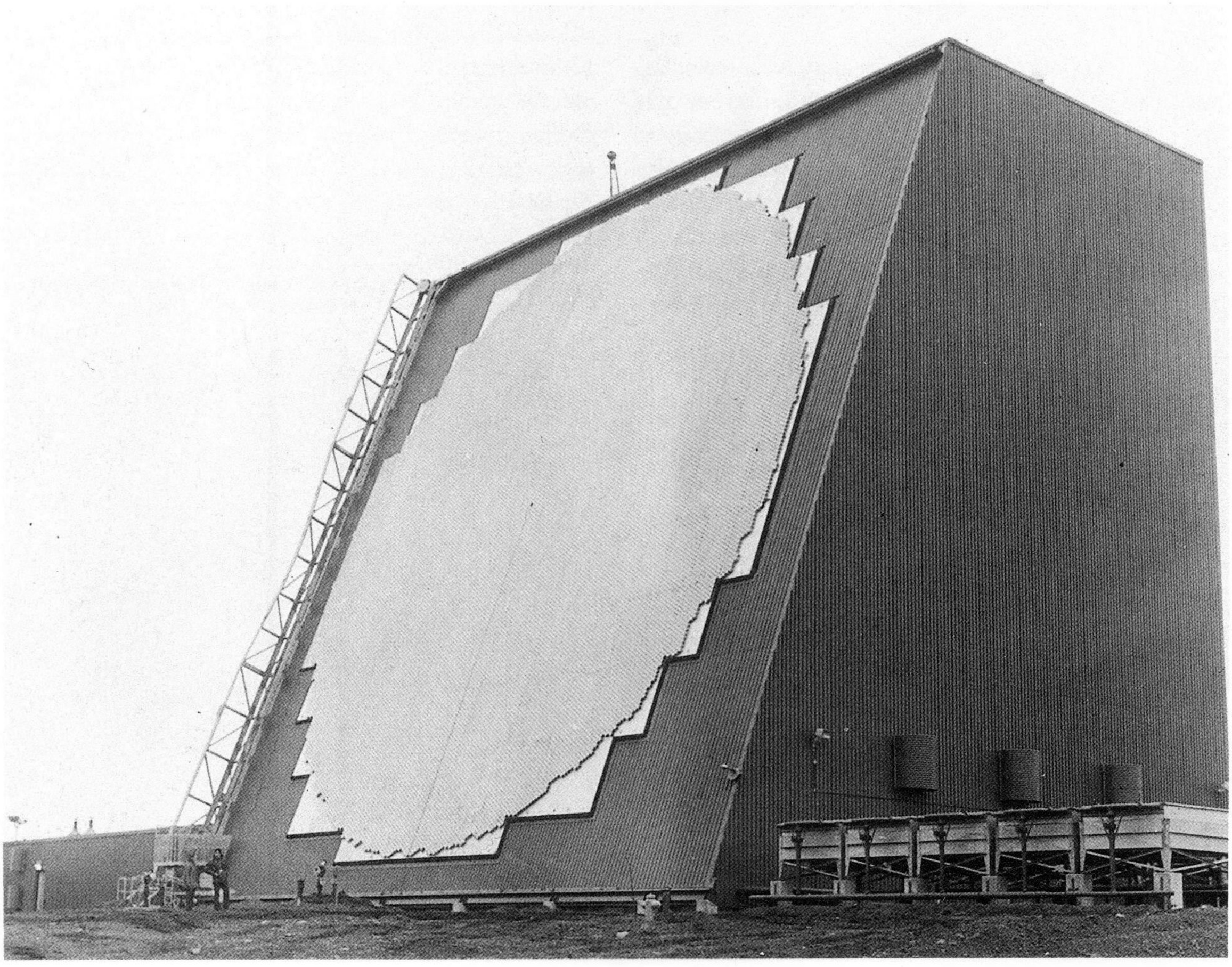
3

Unseen by Radar

FOR DECADES the author has been amazed that aircraft designers appeared to ignore the need to make combat aircraft difficult to see on enemy radars. The man who did more than anyone else to invent radar, Sir Robert Watson Watt, wrote in January 1936 that it would be logical for future bombers to be designed so that their RCS (radar cross-section, in other words their apparent size on enemy radar displays) would be a minimum. This is obviously just common sense. Incredibly, nobody seems to have bothered about this self-evident requirement until very recently. The author discussed the matter with the designers of Britain's V-bombers, the USAF B-52 and B-70 and France's Mirage IVA, and was assured that minimizing RCS played virtually no part in the design process.

So far nobody has explained why this obvious objective was ignored for almost half a century, but

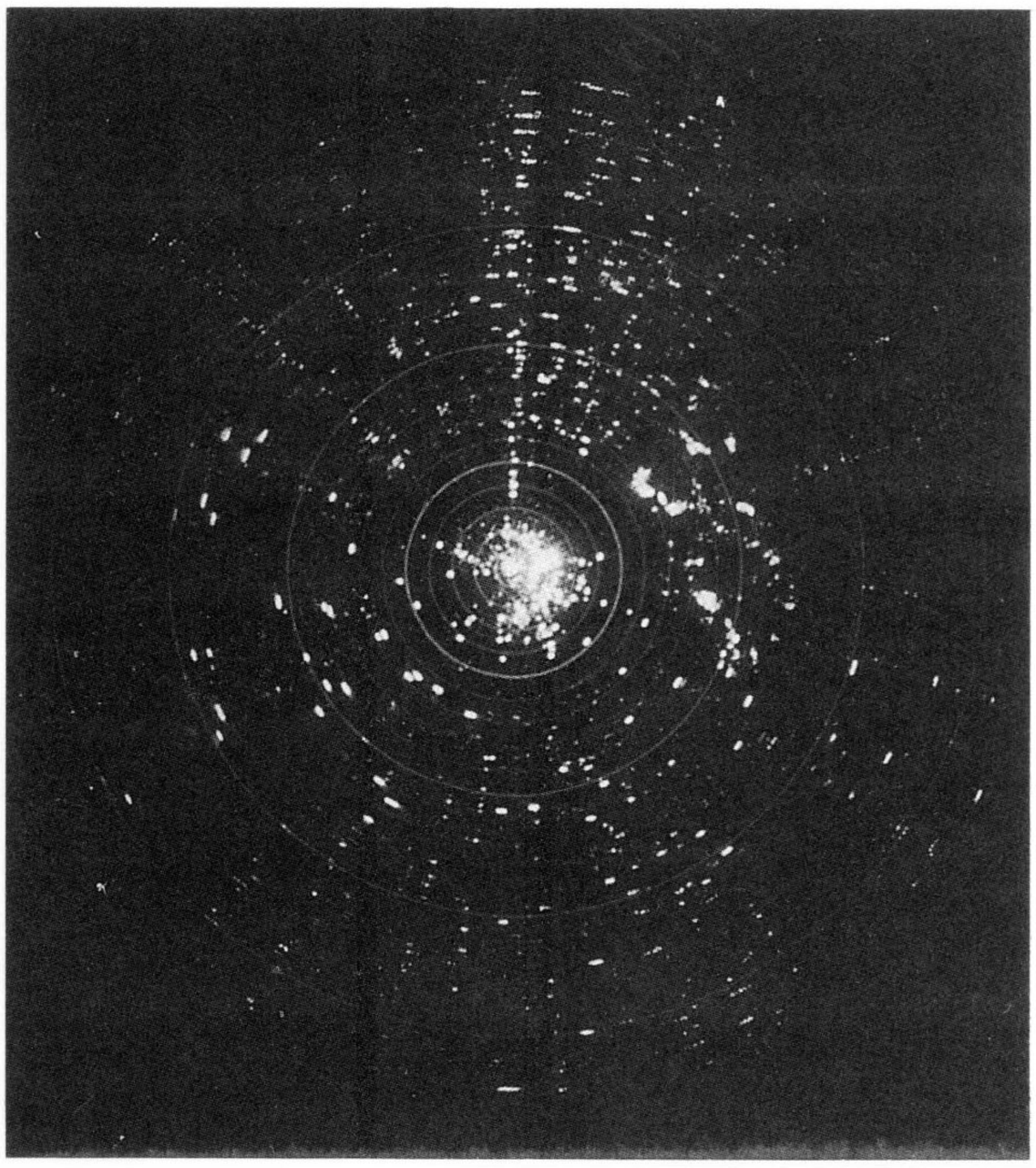
Below: Radars naturally have grown steadily more powerful and better able to detect true targets against clutter and jamming. This is an electronically steered American Cobra Dane tracker.



at least the message has now got through. Indeed, when people today talk about stealth they think first of all about radar, and sometimes overlook the fact that this is merely one out of four ways in which the presence of an aircraft can be detected. Radar is at present the most universally used way of detecting aircraft at a distance. In principle radar is very much like the traditional searchlight: both emit EM radiation, which for practical purposes can be assumed to travel in straight lines at the speed of light, and hope to "illuminate" a target whose presence is detected by sensing the radiation reflected back or scattered away from it. The main difference is that searchlights operate at the very short wavelengths of visible light while radars operate with microwaves, which are exactly the same but have wavelengths of a few centimetres (say, about an inch or two). Other EM waves include heat (IR), and ordinary radio waves.

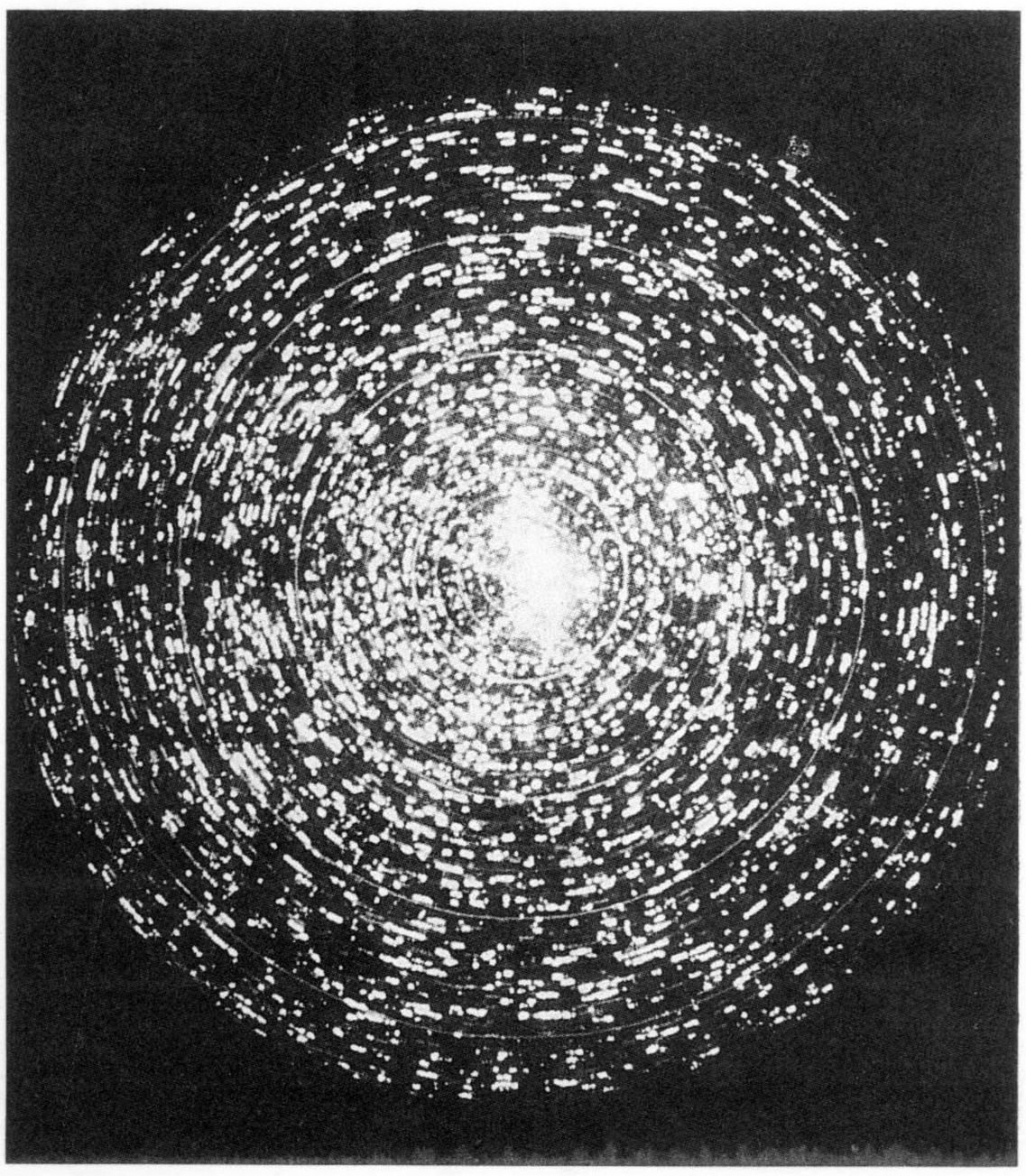
Radars exist in many forms, some so small they could be held in the hand and others as large as the world's biggest inhabited buildings and consuming as much electrical power as a city. They pump out different kinds of signals, the two most basic forms being CW (continuous wave) and pulse. These are self-explanatory, CW being more akin to the beam from a searchlight and pulse being intermittent, rather like the dots and dashes of Morse code.

Many modern radars also make use of the doppler effect, which is best illustrated by the pitch of the sound of an oncoming vehicle—an aircraft, speeding car or whistling train, for example. It is high as the vehicle approaches, falls as it goes past and stays at the lower level as it recedes into the distance. Doppler radars can not only give the range and direction of a target but also its relative velocity.



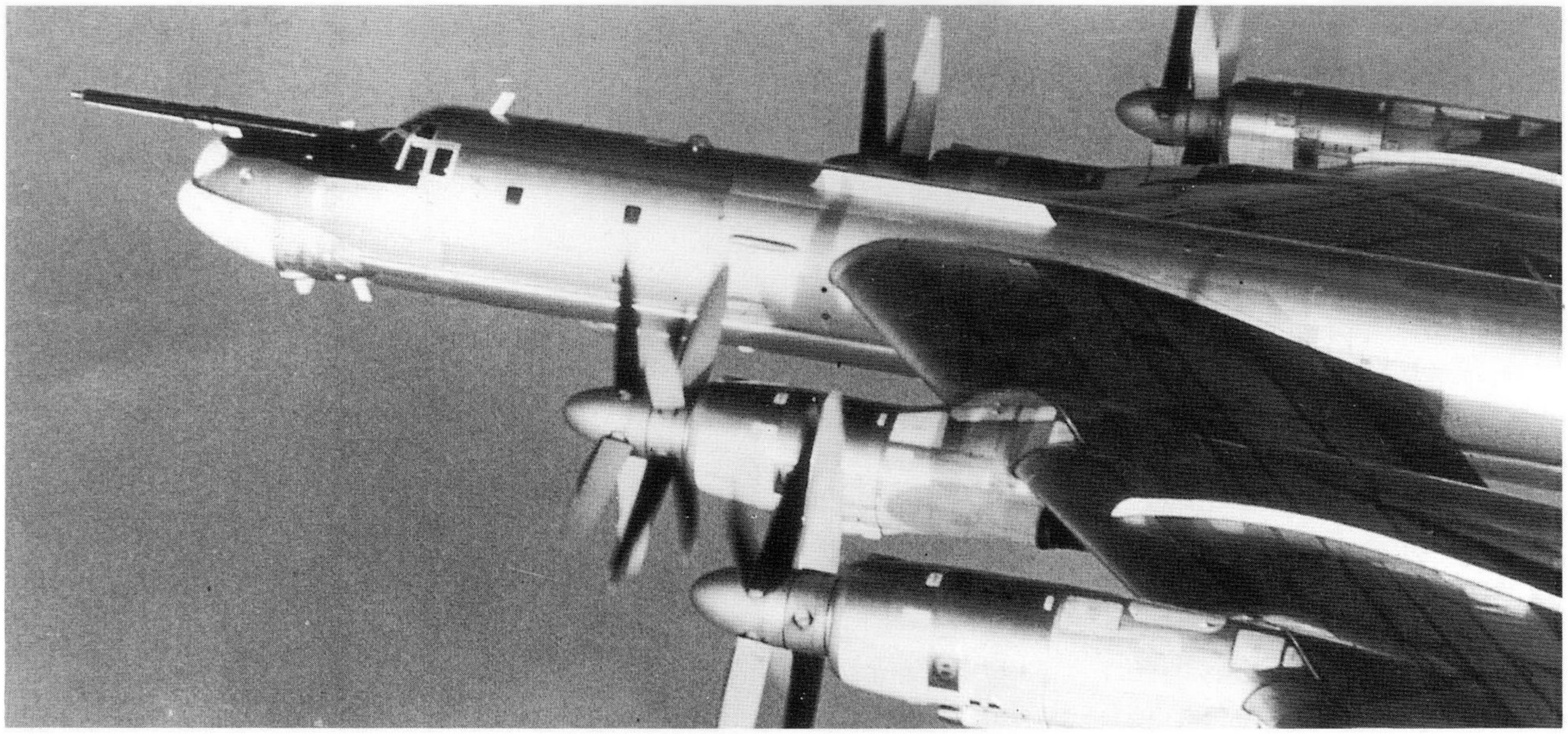
Above: A typical plan-position display from an air surveillance radar of traditional type, showing a large number of true targets in the presence of what appears to be mild ECM jamming. Skilled operators would "see" the true targets with ease.

Below: Powerful ECM jamming, or simple clouds of chaff, create a dense mass of echoes. This display indicates barrage jamming, through which hostile aircraft might be able to penetrate. But such activity clearly tells the defenders an attack is imminent: stealthy aircraft are obviously preferable.



Reflection of radar signals

This book does not need to delve into the technology of radar, which is extremely complex, nor into precisely *how* radar signals are reflected back from an aerial target, which is also a surprisingly complicated process. Suffice to say that the reflection of radar waves from a solid surface closely resembles the reflection or scattering of light waves. A flat polished metal surface is a good reflector, but the reflected ray probably does not go back the way it came. Where flat surfaces meet, as for example at the junction of a fuselage and a wing or tail, there is a



Above: The latest version of the giant Soviet Tu-142, called Bear-H by NATO, is a cruise-missile carrier with such a large RCS it needs very sophisticated EW suites to survive.

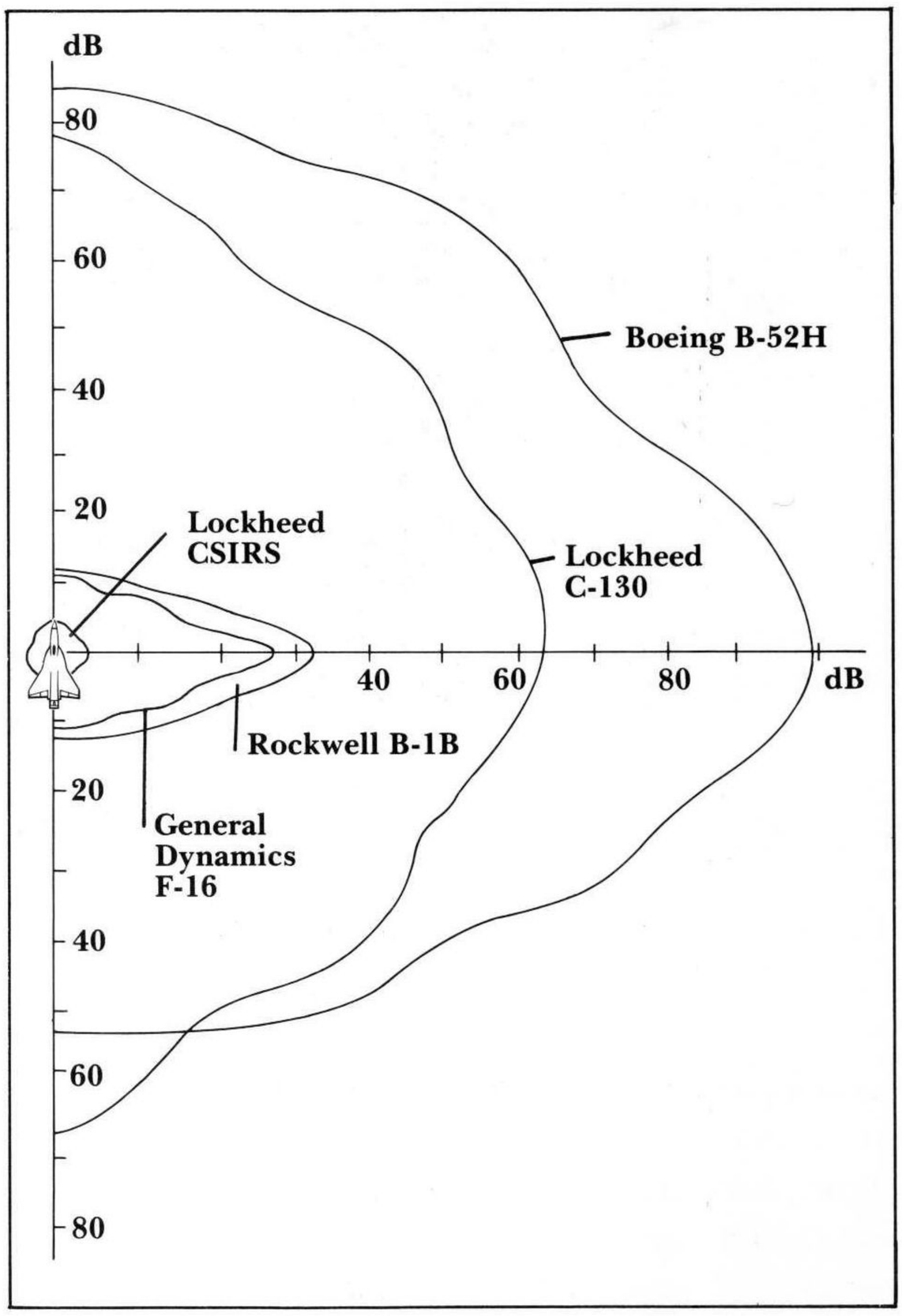
much greater chance of radiation being reflected back along its incident path. This is what is needed for a radar to work, because almost all radars use the same antenna for both transmission and reception and usually the received signals are thousands or millions of times weaker than those being sent out.

How, then, do we make aircraft invisible to radar? The first point to note is that building a stealth aircraft is totally different from using techniques to thwart the enemy radar's ability to pinpoint the range and direction, and possibly speed, of our own aircraft. The simplest ECM is chaff, billions of small slivers of reflective material such as aluminized plastic film, which fill the sky with reflective surfaces and completely swamp the enemy's display with echoes. This makes the screen one mass of brightness, in which the single "blip" (echo) caused by one's own aircraft cannot be detected. There are various other devices, such as active jammers which pump out energy on the same wavelength as the enemy's radar, which again flood the display screen with brightness to mask our own echo.

The weakness of all these ECM techniques is that, while they hide the exact position of our aircraft, they positively broadcast the fact of our presence. Of course, a cunning air force might—for example—fire chaff-packed missiles into enemy airspace when none of its own aircraft were operating, so that eventually the enemy would cease to take any notice. Then, when an attack mission was actually taking place, the enemy would be lulled into once again ignoring what was happening. ECM is one extremely important technique, which in today's era of non-stealth aircraft is absolutely crucial to survival in hostile airspace. But clearly, it is very much better to be stealthy and undetectable than to make a tremendous commotion and fill the sky with radar reflectors, which is what bombers and attack aircraft do today.

RCS reduction

To return to the basic question of how we can become invisible to radar, this ultimate objective is obviously not quite attainable with practical military aircraft. Smaller targets, such as microlights and cruise missiles, can be made virtually undetectable, at least by today's radars. Bombers and attack aircraft are very much bigger, can weigh hundreds of tons, and unless we are very clever could provide a radar target like the proverbial "barn door". The point was made earlier that today's warplanes, almost without exception, were designed without any attention being paid to Watson Watt's self-evident guideline of 1936. Two particularly juicy radar targets are the Soviet Tu-20/142 "Bear" and American B-52. The former has four contra-rotating propellers of well over 18ft (5.6m) diameter, each with eight broad paddle-like blades which in cruising flight are almost



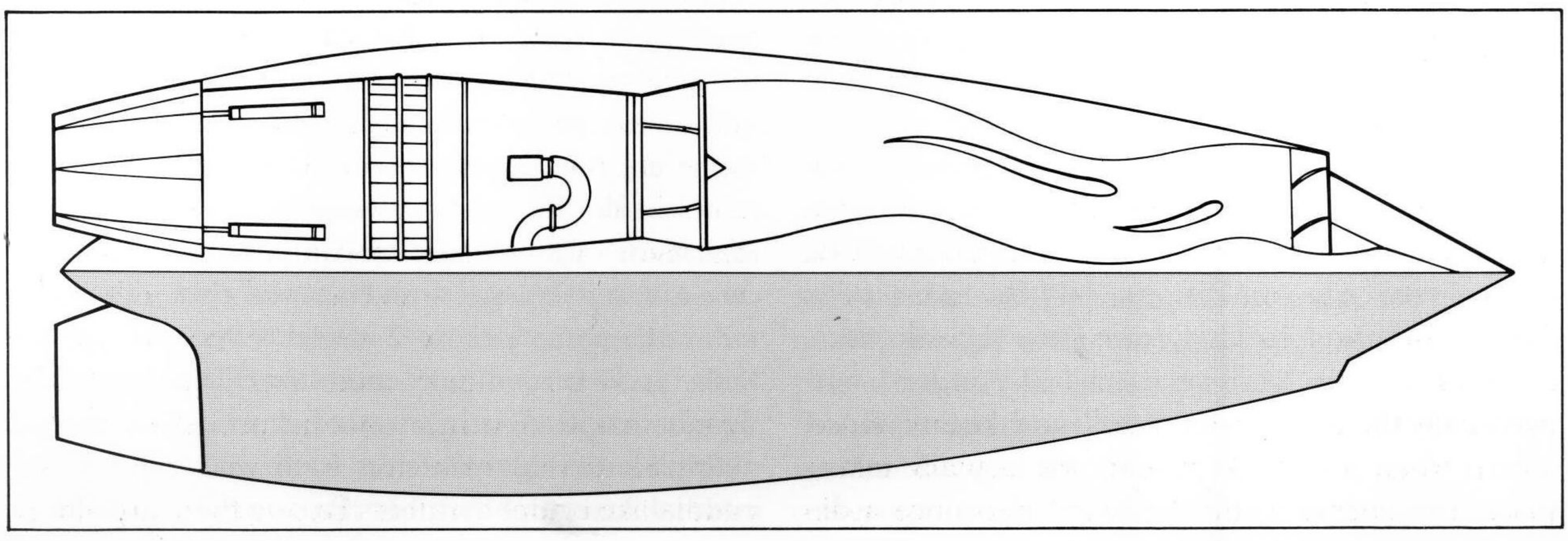
Above: RCS varies depending on the aspect of the target (the angle from which it is seen). It is possible to plot values all round an aircraft viewed from its own level (not from above or below), and these curves show such plots for common US types. The right half of the plot is shown, the left half being a mirror-image. In each case the aircraft is pointing towards 0°; thus, 090° is broadside-on.

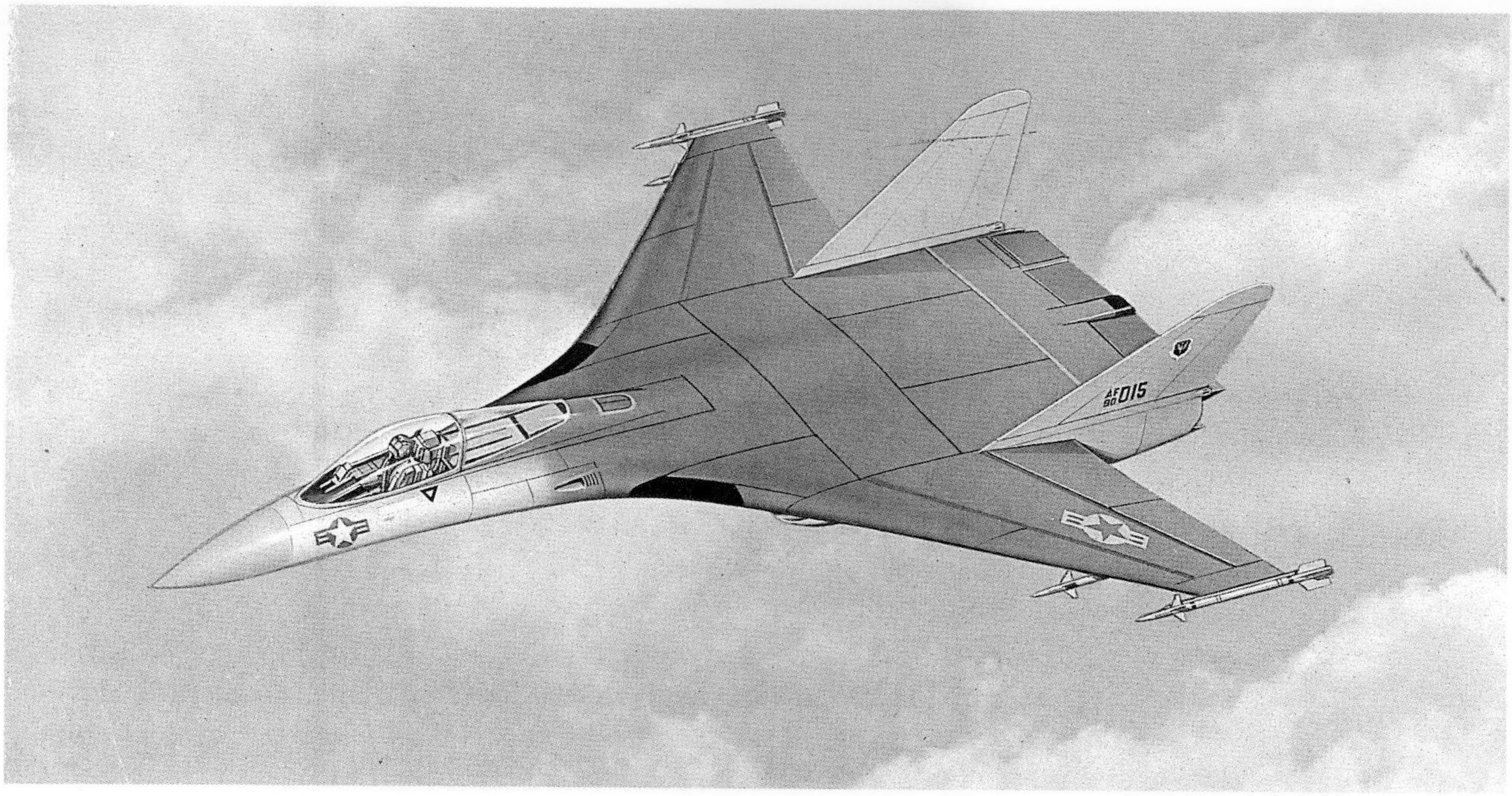
Below: Precisely how the engine inlet ducts of the Rockwell B-1B are arranged is classified, but this diagram shows the general idea. Without degrading aerodynamic efficiency significantly, baffles are arranged to prevent radar beams from reaching the reflective engines. They also reduce noise.

broadside-on to a radar watching from directly below. The B-52 has eight engines whose inlets and first-stage compressor blades are in full view of a radar ahead and make excellent reflectors. From other angles the B-52's vast slab-sided fuselage, nacelles and pylons and giant fin make some of the best radar targets in the sky.

The B-52's main replacement is the B-1. The first version of this almost equally large bomber, the B-1A, has an RCS only about one-tenth as great as that of the B-52. It was not difficult to achieve this result, because the older bomber's RCS is so horrendous. Indeed, mere streamlining to enable the B-1A to fly at Mach 2 achieved most of the reduction. The greater challenge was today's B-1B, now in wide service with USAF Strategic Air Command. Though it looks almost the same as a B-1A, apart from being painted not in anti-flash white but in dark camouflage (two shades of grey and a dark green) the B-1B is actually very different. It is designed to fly not at Mach 2 at high altitude but at subsonic speed at 500 ft (152m), and one of the most important changes has been total redesign of the inlets and air ducts to the four engines.

The B-1B has ducts containing long wall-like baffles which, without interfering significantly with the hurricane flow of air, make it impossible for any radar to "see" the fronts of the big turbofan engines. The baffles, like most of the rest of the visible skin, are specially designed to entrap or scatter radar signals. Large areas of the aircraft skin are covered with RAM (radar-absorbent material), and the camouflage paint is also specially formulated to absorb radar energy. As a result the RCS of the B-1B is only one-tenth as great as that of a B-1A, or one-hundredth that of a B-52.





Above: Rockwell used B-1B experience in scheming this Advanced Fighter Concept in 1983. Though over 60ft (18m) long, it would have had an extremely small RCS.

This achievement is all the greater in that the B-1 was not originally a true stealth design, though for once the importance of achieving low RCS was taken into account. Obviously, if one sets out with the proverbial clean sheet of paper to create a bomber with the smallest possible RCS then one can do even better. On the other hand, like almost every aspect of aircraft design, the final outcome is inevitably a compromise. The absolutely ideal stealth bomber would be so inefficient as a bomber, and probably so difficult to fly, that it would be unable to do a useful job. A practical bomber has to have reasonably efficient engine installations, a very efficient wing in order to carry heavy loads long distances, a good cockpit, a powerful and effective flight-control system and, not least, safe and pleasant flying qualities.

On the other hand, these basic demands do not preclude the attainment of near-invisibility when confronted by today's radars. The most basic demand of all, that the aircraft should have an efficient wing, is not onerous. Bearing in mind that tomorrow's warplanes will continue to penetrate hostile airspace at very low level, the wing will be seen almost edge-on (except by the radar of a defending fighter, looking down from high altitude). An edge-on wing has a very small RCS indeed, and with suitable attention to detail and use of RAM surface skin and special paint it can be made essentially invisible. So the basic task of the aircraft designer is to create an "invisible" wing and then leave out everything else. This is pretty much what Northrop have done with the ATB, as explained later.

Designing the structure

How do we construct the external parts of an aircraft to have minimum RCS? Clearly, we must start by so shaping the aircraft that all parts blend into each other with smooth curves, with as few flat surfaces as possible, and taking particular care to try to avoid large flat surfaces that meet at approximately a right-angle. Secondly, we must try to design the structure behind the skin in such a way that radar waves passing through the skin are in some way lost without trace. One way of doing this is to use sandwich type material in which inner and outer sheets are bonded to a filling which can be a metal honeycomb or similar structure consisting of thousands of small cells or compartments. If these cells are suitably sized and shaped they can make radar energy race around inside, reflected from the walls, and be so rapidly attenuated that no useful signals escape. Another way of causing this kind of multiple internal reflection is to make the major internal structural members face each other with an



Above: Like its much faster stablemate, the SR-71, the Lockheed TR-1 is covered in black "iron ball" paint to minimise RCS from all aspects.

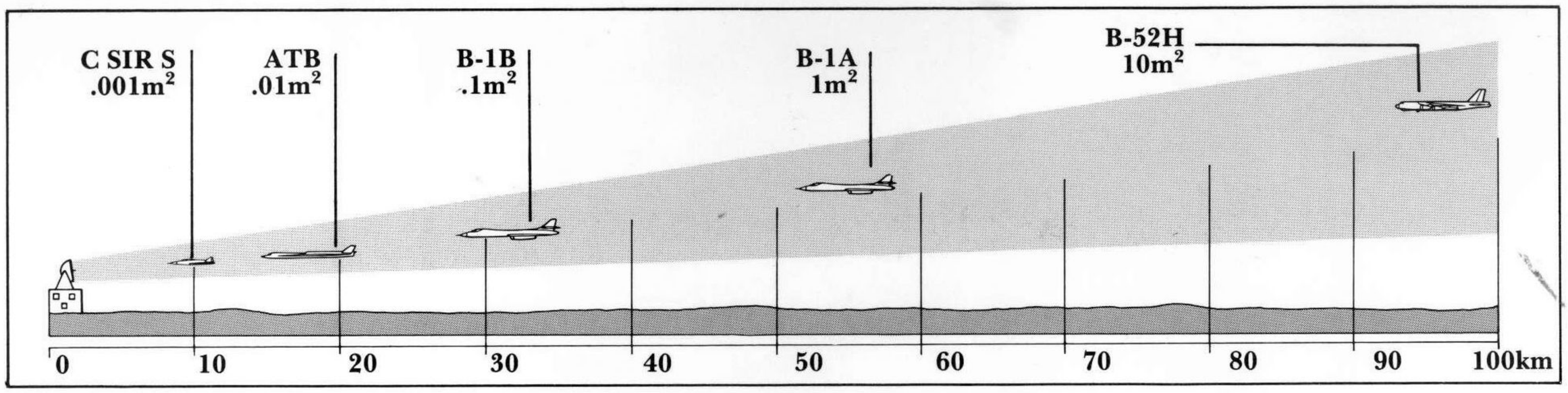
acute angle between them, like a V. The radar waves then tend to be reflected from each side of the V in turn, finally "disappearing" into the cul-de-sac.

There are many ways in which we can cut apertures in a metal skin in order to make incoming and outgoing radar waves cancel out. These apertures can be slots, crosses and various other forms, which behave in exactly the same way as flush suppressed antennas built into the skin of many of today's aircraft to serve communications radios and other avionics. As the whole subject is deeply classified it is not possible to say precisely how or where cut-outs in the skin are used in current and projected stealth aircraft, but obviously this is the last thing the structural designer wants to do in skins subjected to high and oscillating stresses, because any cut-out not ony greatly weakens the panel but also causes a concentration of stress at any corner or end of an aperture, the concentration being inversely proportional to the radius of curvature at the edge.

Considerable research has been done on the practicality of covering a completed aircraft with tiles or sheets of RAM type. Various forms of sandwich and honeycomb slabs have been investigated, but some of the problems are obvious. The basic aircraft has to be designed to be undersized, so that the final form on the outside of the tiles has the correct aerodynamic shape. The tiles have to be so firmly attached and tough that they will withstand normal service wear and tear and the impact or erosion of flight at supersonic speed through hail. Many of the problems are related to those attending the use of thermal insulating tiles on spacecraft designed to withstand re-entry to the Earth's atmosphere, such as the Shuttle Orbiter. It is doubtful that an externally applied RAM layer of this type is in use on any of today's stealth aircraft.

Black RAM paint

What is known to be in use, and for a quarter of a century, is "iron ball' paint. There are at least two fully developed and approved paints of this kind, one being of Japanese origin but licensed to a manufacturer in the USA. These RAM paints look much like any other paint, and can be applied more or less in established ways. Under a powerful microscope they can be seen to comprise billions upon billions of tiny ferrite balls surrounded by a special adhesive liquid. The balls are so small as almost to qualify for the term "powder metallurgy", but they play a crucial role in the electronic performance of the paint because they are very powerful magnetic materials; they are commonly used, for example, in core memories of computers and in magnetic tapes.



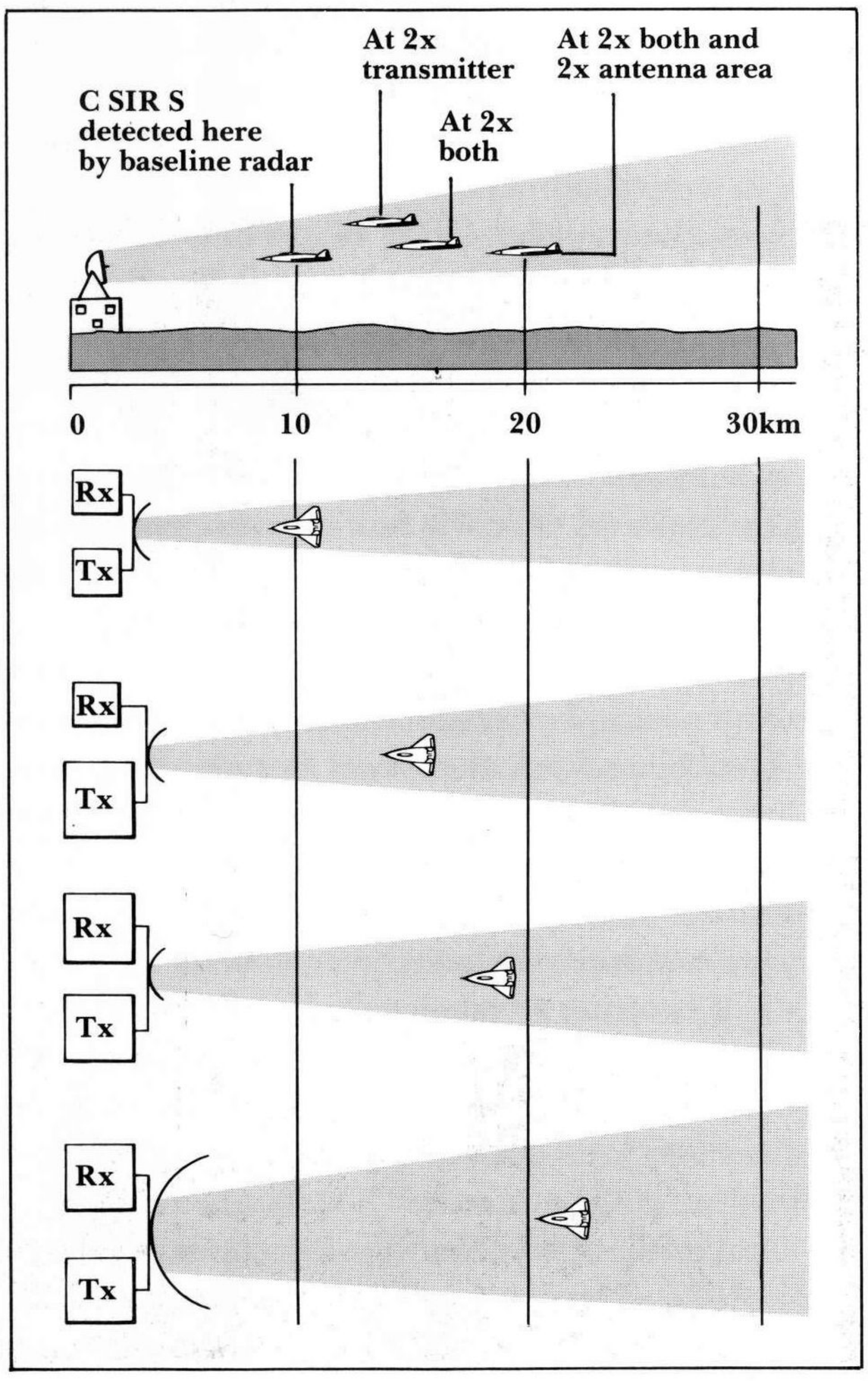
Above: A graphic representation of the effect of stealth design on typical radar detection distance. The actual RCS of the five USAF bombers cannot be published, but are known to have approximately this relationship one to another. It can be seen that a 1,000-fold reduction in RCS does not result in anything like a 1,000-fold reduction in detection range. Obviously, true radar "invisibility" is impossible.

Ferrites are not pure iron but often carefully structured oxides of iron and at least one other metal.

So far the only well-known ferrite paint is dull black, and it completely covers the Lockheed SR-71 and TR-1. When such an aircraft is illuminated by radar, the waves striking the layer (or, it is believed, layers) of paint generate local electromagnetic fields and currents which precisely cancel out the original wave or signal so that virtually nothing gets scattered away. Certainly nothing gets reflected, mirror fashion, and thus the RCS is reduced close to zero. Iron-ball paint lasts reasonably well, and does not greatly add to the burden of maintenance, but it has to be treated with respect. It is of course fairly weatherproof, but (though the author finds this difficult to comprehend, because ferrites are already oxides) the story is current in the USAF that if you leave an SR-71A out in the rain it can become streaked with rust!

To every action there is usually a reaction, or counter-action, and certainly to every weapon in history there has eventually arisen a counter-weapon. As there is almost no possibility of ever making a stealth aircraft that is truly invisible to radars, it follows that all that an enemy need do to see such aircraft more clearly on radars is to develop improved radars. Ground-based radars can have almost limitless power, and in theory doubling the transmission power approximately doubles the size and clarity of a faint echo. Again, stealth aircraft are designed on the basis of particular assumptions about an enemy's radar, and major changes in wavelength, waveform, antenna size and type, and the ability of radars to distinguish moving targets against a fixed background, all can be made to enhance the radar signature of a distant target with a very small RCS. One must expect this "cat and mouse" game of action and counter-action to continue indefinitely.

Below: What can the enemy do to detect low-RCS aircraft at greater distances? If a Lockheed recon/strike aircraft can remain undetected to 10km by the hypothetical baseline radar, it will become visible at 12km with doubled transmitter (T) power, at 15km with doubled T plus doubled R (receiver sensitivity) and at about 20km with doubled T, doubled R and also doubled antenna area. Thus, gains are modest.



4

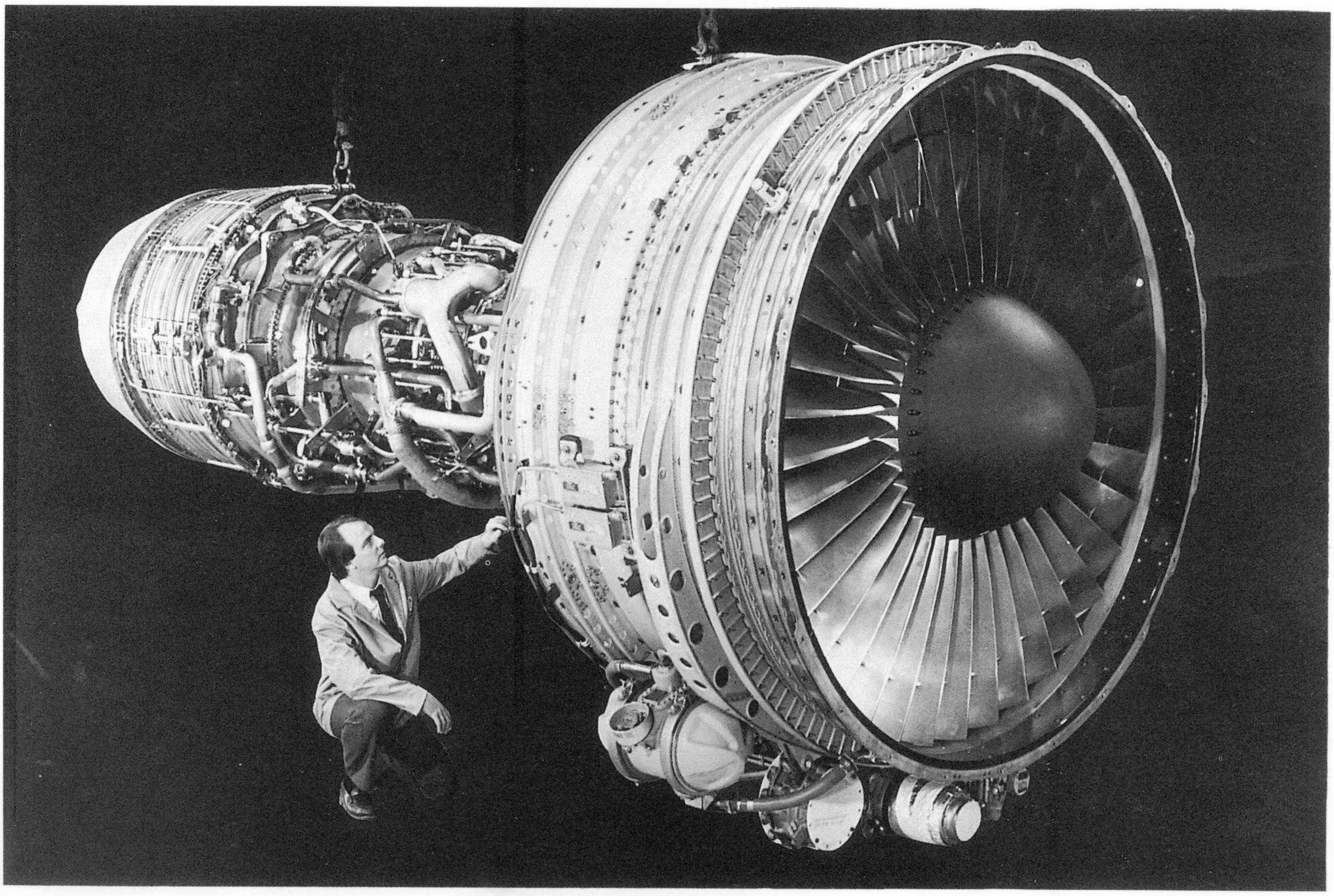
No Sound, No Heat

FORTY YEARS AGO airshow crowds thrilled to the exciting new sound of jets, and 30 years ago their chests vibrated with the assault of soundwaves from giant afterburners. Today, and perhaps to the regret of pilots and young enthusiasts, we have to accept that this is all bad news. The air force of the future has to be so quiet we hardly know it's there. It may be unexciting, but it's better than being shot down.

Since the late 1950s designers of commercial jetliners have had plenty of experience of making engines quieter. One gigantic step forward was the introduction in 1970 of HBPR (high bypass ratio) turbofan engines. Instead of being long and slim, these engines are short and fat, those of big wide-body aircraft having air inlets a man can walk into standing upright. The giant fan is almost like a ducted propeller, and generates almost all the engine's thrust. Such engines are not only quiet but also, because of their low mean jet velocity, they are extremely efficient and burn much less than half as much fuel as equivalent turbojets of the previous generation.

They are ideal for military transports, AWACS-type radar platforms, ocean-patrol aircraft and certain other aircraft where range and endurance is more important than speed. Such aircraft will in

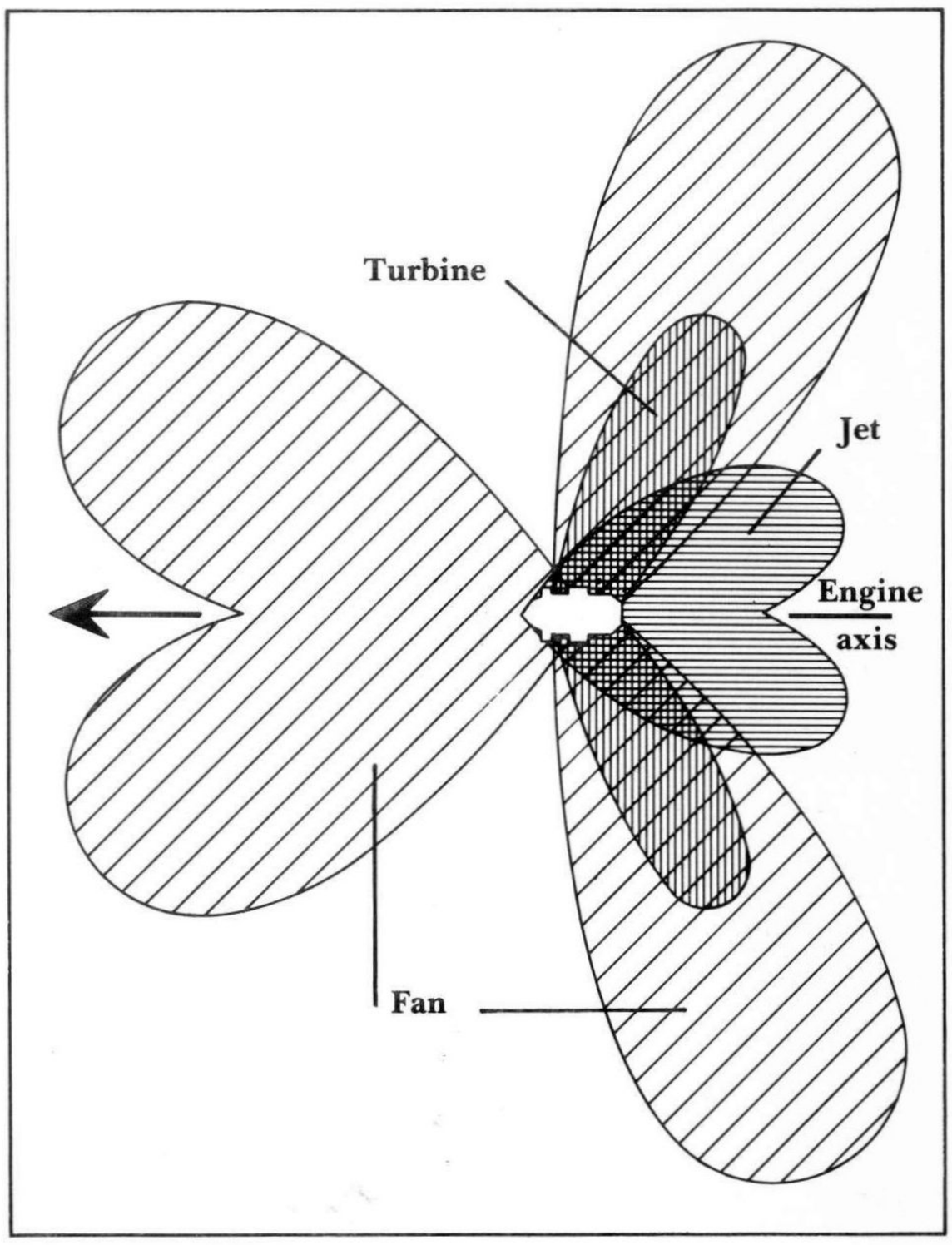
Below: A General Electric engineer gives scale to a CF6-50, a typical HBPR engine. Almost all the thrust comes from the giant fan, driven by the slim, hot core engine behind.



future have to be of stealth design, if they belong to an air force, but this book is concerned chiefly with aircraft intended for direct combat operations against the enemy, in either offence or defence. For these the giant HBPR engine is unlikely to be entirely suitable, though for various reasons all stealth aircraft will have to entrain a flow of fresh air around each engine which in effect does convert the propulsion system into one of HBPR type. In other words, into one in which most of the air coming in at the front is bypassed around the core of the engine—the high-pressure white-hot heart of the engine consisting of the high-pressure compressor, combustion chamber and turbines—and forms a cool tube of relatively slow-moving air surrounding the hot central jet from the core.

Though it is almost certain that the engines of future fighters and bombers will be turbofans, these are likely to be of a slimmer low bypass ratio type, which are essential for supersonic aircraft because of their low frontal area. These are inherently noisier than the HBPR variety, and a higher proportion of their total noise is generated by the jet. But jet engines create several kinds of noise, and the noise heard at a distance from the aircraft is strongly modified by the engine's installation. Engine manufacturers plot the noise spectrum around a bare engine, as run on the testbed, after taking measurements all round from dead ahead, round the left side, passing to the rear and back round the right side to dead ahead again. Further measures are then made right round the completed aircraft, which of course is usually quieter because the engine is inside a nacelle, fuselage or other surrounding structure.

Below: A typical noise plot around an HBPR turbofan. Unlike a turbojet, which is dominated by the thunderous jet noise, the main HBPR noise comes from the fan. It is very directional.



The noise spectrum

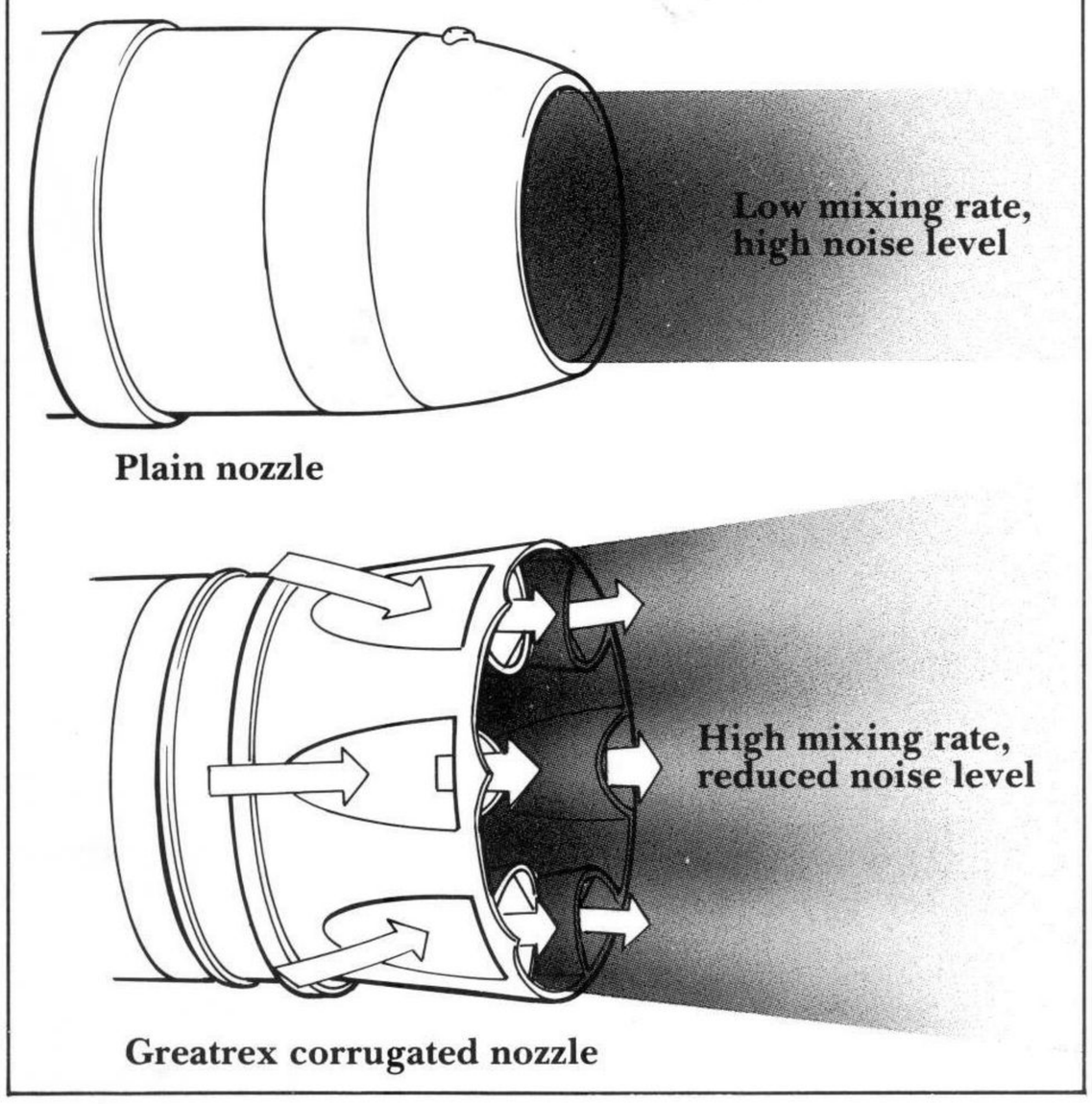
Of course, like light, heat and radio waves, noise is a spectrum of wavelengths, from slow vibrations that we cannot "hear" but which we can feel, through the entire aural range that humans can hear, up to ultrasonic high-pitched noises that dogs can hear but humans cannot. There is not much point in eliminating the human-audible sounds if we leave intense high-frequency noise that could be detected by a defence system. And, right at the outset, we have to recognise that making a powerful warplane absolutely silent is yet another pipe-dream. All we can do is make it extremely difficult to detect. Even this means cutting down the noise signature about one-millionfold, compared with combat aircraft of today.

Noise is created by the passage of the aircraft through the atmosphere, but a stealth aeroplane is likely to have such a clean aerodynamic design that this source of noise is almost certain to be insignificant. If a Northrop ATB were to fly past with engines throttled back it would make no more sound than a flypast by a championship sailplane with airbrakes retracted—which is very little noise indeed! Far more important is the noise generated by the engines, and this is caused by three main sources: the fan or LP compressor, the turbine(s) and the jet. In HBPR engines the fan noise is usually dominant, but in warplanes the main source of noise is usually the jet.

When an aircraft penetrates a great distance through hostile airspace its noise spectrum all round is important; there is no point in reducing fan noise ahead of the aircraft if it has a deafening jet at the rear. One in an attack on an isolated target, such as a single warship in open ocean, is the noise signature

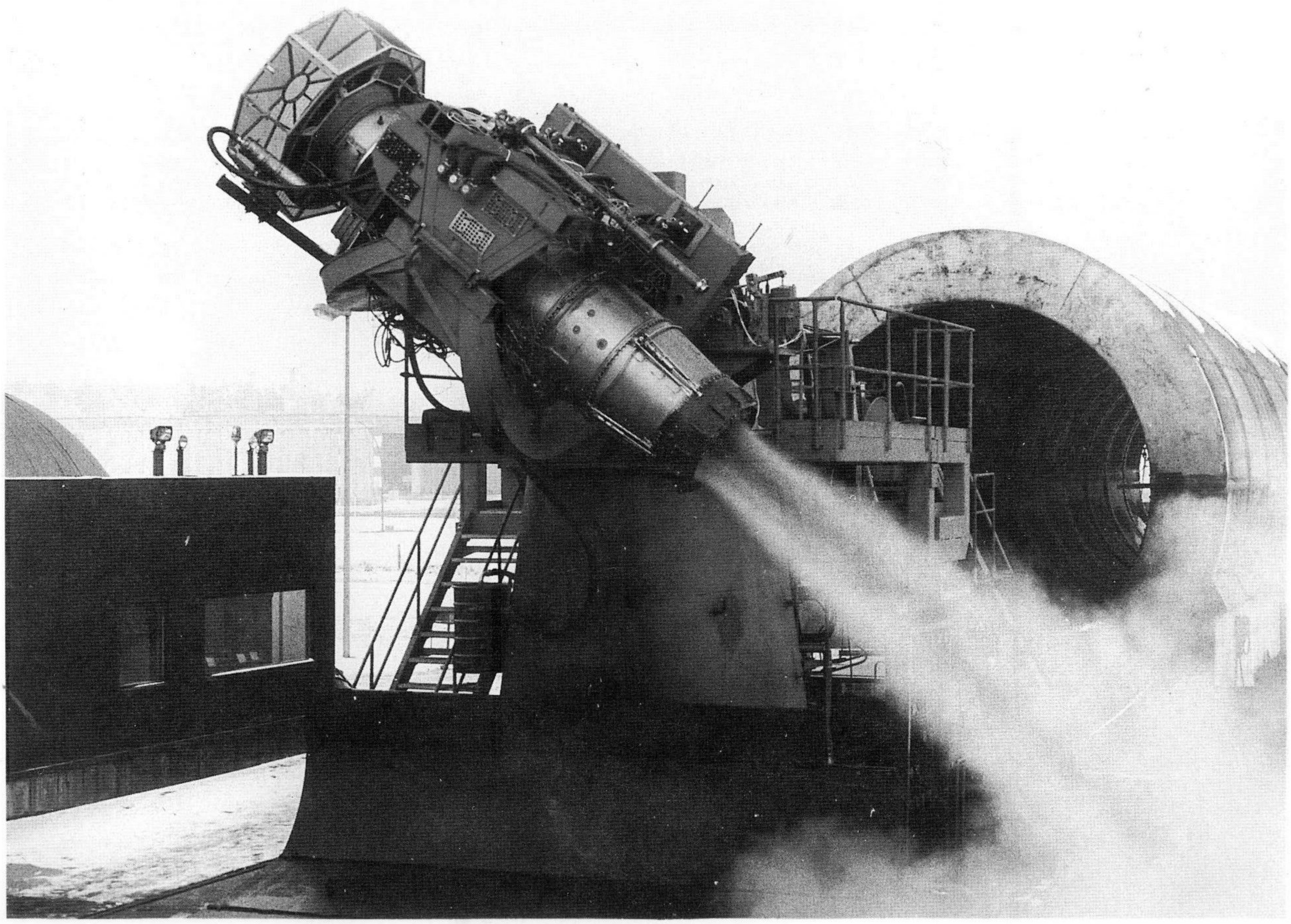
from ahead of paramount importance—unless the aircraft is supersonic at low level, which would provide an ideal answer, but one which is unlikely to be achieved.

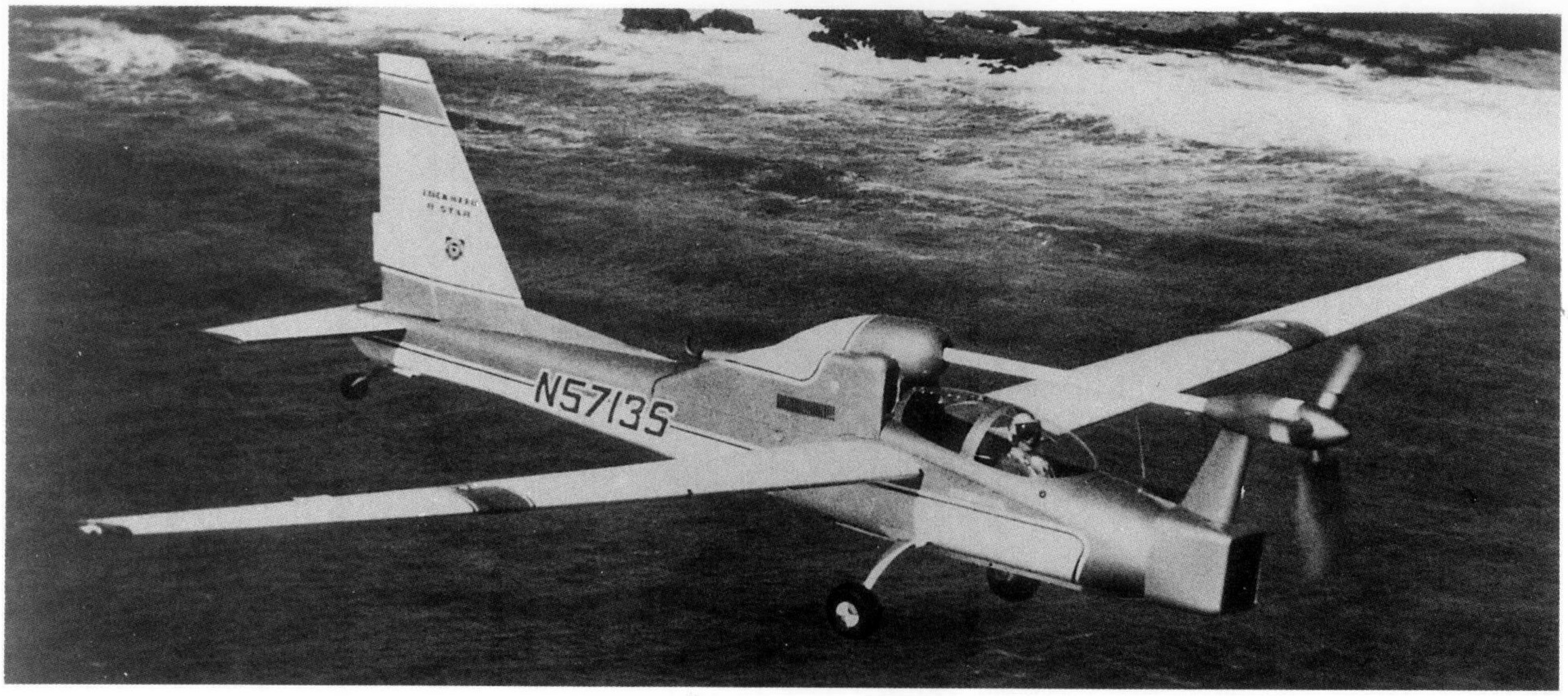
Fan noise projected ahead is made up mainly of discrete tones, in other words of actual musical notes, whose frequencies are determined by the numbers of fan blades and the rotational speed. The engine designer does his best to improve the design of the successive moving and fixed blades so that the turbulent wakes downstream of the blades are smoothed out, and to choose different numbers of blades in successive rows to cut down the harmonics and powerful tones that would be generated by having, say, a ring of 36 fixed stator blades immediately upstream of a ring of 36 moving rotor blades. This kind of noise is also strongly attenuated by having a long inlet duct with radar-absorbing baffles and splitter plates, such as a stealth aeroplane will prob-



Above: In the 1950s Rolls-Royce pioneered the Greatrex nozzle in which a long corrugated periphery promotes rapid mixing between the jet and surrounding air, reducing noise.

Below: Testing an RB199 Tornado engine, with oil injection to render the jet visible. This is not an HBPR engine, and most of its noise is generated by the high-velocity jet.





Above: The first attempt to build a silent aeroplane was the Q-Star, by Lockheed Missiles & Space Co. It flew with various engines and slow-running wooden propellers.

ably have in any case to reduce its RCS. It is not too difficult to make an installed engine very quiet indeed from the forward 180° sector, so the chief problem remains jet noise from the rear.

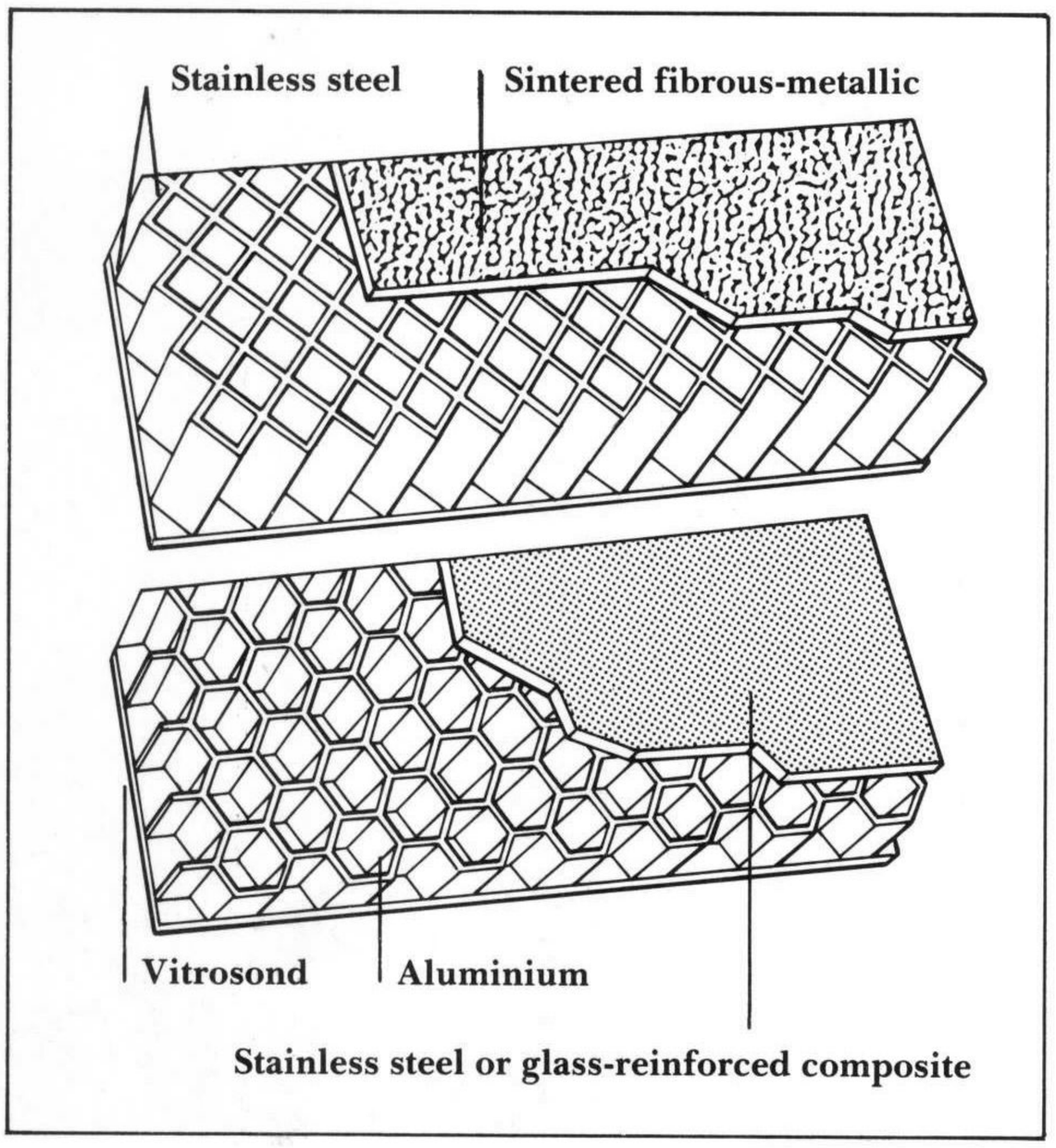
Again, stealth design to reduce RCS and IRCS (infra-red cross section) goes most of the way towards reducing noise. But we can take measures specifically intended to cut down on the external noise. We cannot do very much about turbine noise heard from astern, beyond the usual reduction in wake interaction between the stators and moving blades and careful selection of the numbers of blades in each stage.

We can, however, do a lot to reduce jet noise. The latter is roughly proportional to the fourth power (mathematical index) of the mean jet velocity. Thus, if we can make the jet slower, we cut the noise dramatically. Of course, if we make the jet slower, we reduce the engine's thrust, so what we wish to do is to make the jet slower and at the same time bigger. This is achieved automatically by the HBPR engine, as in a 747 or Airbus, but we have to use a slimmer engine. The solution, therefore, is to make the jet entrain a lot more air around it.

In the first jetliners a step was made in this direction by adding a noise-suppressing nozzle. A plain nozzle blasts out a high-velocity jet which causes intense noise at the boundary between the jet and the surrounding air. Suppressors replace the simple hole by a nozzle with multiple lobes which give the jet a cross-section rather like a many-petalled flower. The wavy outline has a periphery much greater than that of the original jet, promoting more rapid mixing, and fresh air is entrained into the spaces between the lobes or "petals".

Stealth aircraft obviously go much further along the same path. The engines are installed deep inside

Below: Typical noise-absorbing materials, as depicted in the Rolls-Royce book *The Jet Engine*. Both are honeycomb sandwiches, the upper one being made of high-temperature materials and thus suitable for lining hot jetpipes.



the fuselage or wing, fed by inlets shielded from radar and emitting the jet from a nozzle either of deeply lobed form or made up of a group of individually lobed pipes facing aft. These pipes have to be so designed that they do not significantly increase back pressure behind the turbine, because this would increase turbine temperature and greatly reduce efficiency. The multiple jets would then entrain a huge additional flow of cold air from the inlet system, and this would both reduce noise and, at least as importantly, cut down the IR signature, as described below.

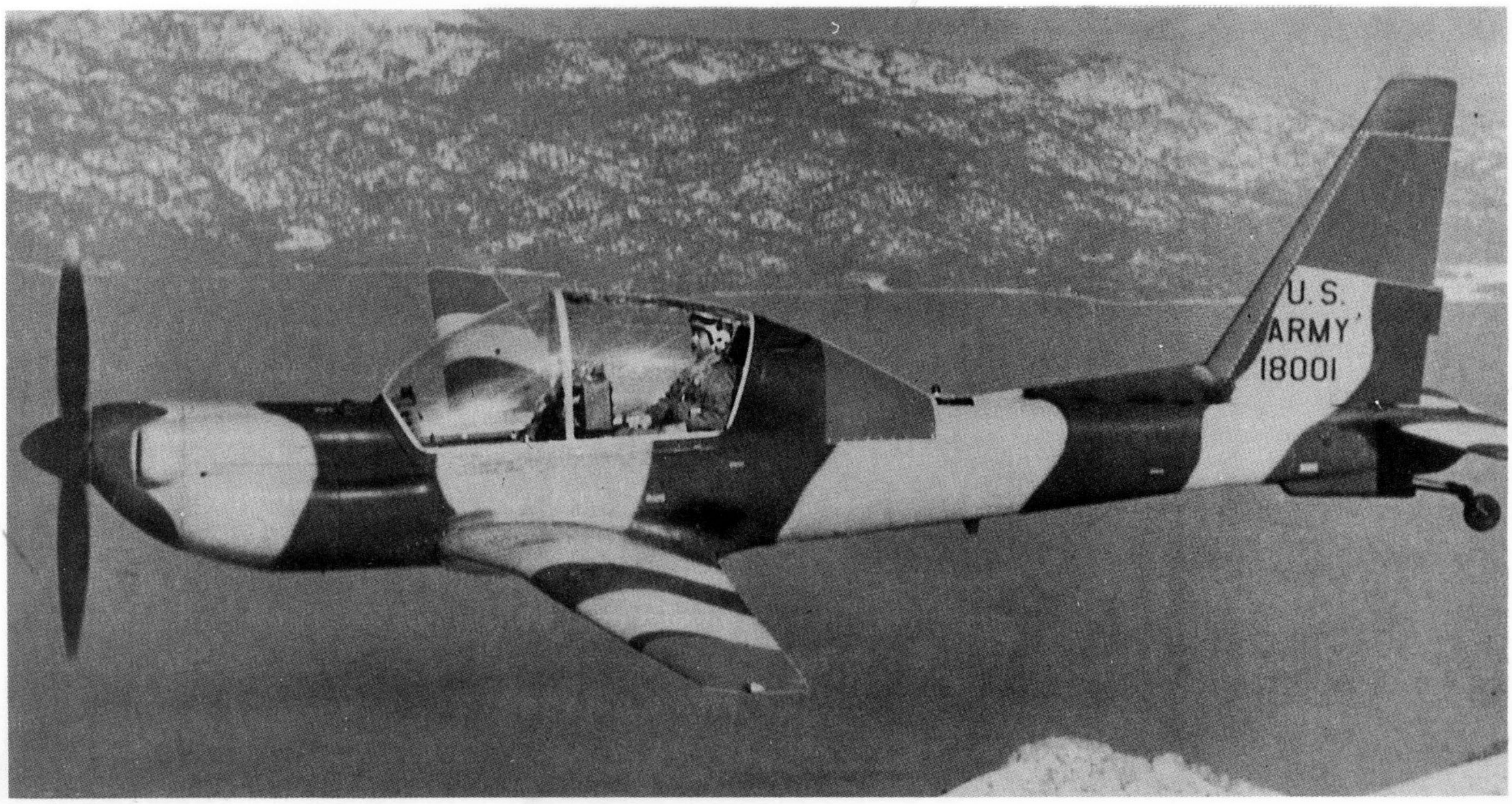
A further extremely important way of reducing aircraft noise is to use special noise-absorbing structure to line the inlet air duct, the jetpipe and surrounding structure. To some degree such structure resembles the radar-absorbent materials previously described. Some are made of metal and others of carbon and other composite materials, but all are sandwich structures in which inner and outer skins are bonded to a core consisting of thousands of enclosed cells which can be squares or honeycomb-like hexagons. In some acoustic panels an aperture is cut in the inner panel in the centre of each of the small core cells. This lets noise energy enter the cell, where it is dissipated. An alternative scheme, said to be used in Lockheed's stealth warplane, is to follow the design of the anechoic chambers in which electronic devices are tested and cover the duct walls with small pyramids with their apices (tops) pointing inwards. The projecting pyramids are said to have a base about 0.5in (12.7mm) square.

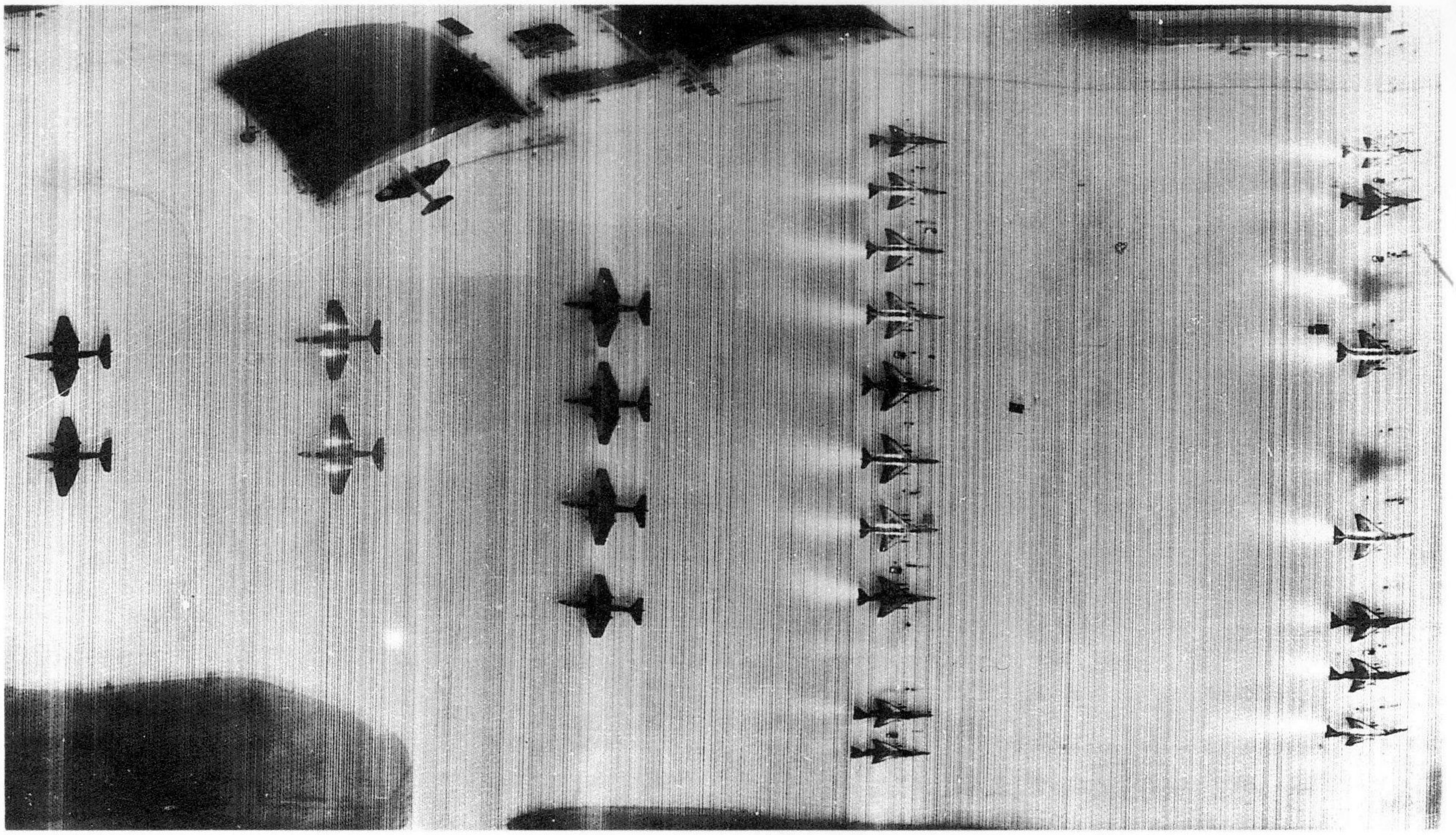
The first deliberately "silent" aircraft were the Lockheed Q-Stars and YO-3A series of covert surveillance machines used in Vietnam. These relatively slow and low-power machines could fly low over enemy troops without making more noise than "leaves rustling in a breeze". Today's Lockheed CSIRS is said to make "a gentle hum at a distance of 100ft (30m)". We can never hope to do much better than this.

Undected by IR

Of all the challenges facing the designer of stealth aircraft the most difficult one to accomplish fully is probably to make it undetectable by devices sensitive to heat (infra-red or IR radiation). Of course, making the aircraft invisible at optical wavelengths and to radars, and completely silent, are also impossibilities, so adding one more may seem superfluous. The point about IR is that a modern bomber, such as the B-1B, when at full power in a sea-level attack pumps out heat continuously at a rate approximately *20*

Below: The Lockheed YO-3A was the first ultra-quiet aircraft to go into service. Developed in 1968–69 for the US Army in Vietnam, it carried a SLAR (side-looking airborne radar) which a well-equipped enemy would have detected.





Above: A British Aerospace IR picture of Canberras and Phantoms. It is easy to see areas that are hot (white). The engines of the stealth aircraft must be the same temperature as the background.

billion times higher than that which could be detected by sensitive IR receivers. So if there were "degrees of impossibility", this one would take the prize.

"Black light"

IR detection of aircraft has a history almost as long as that of radar. Back in 1941 the Luftwaffe fitted a sensitive IR detecting device called a *Spanner-anlage* into Do 17Z-10 and Bf 110D-1/U1 night fighters. This was an active device. It did not just snese an aircraft's exhausts, but "illuminated" it with IR, using a kind of searchlight using heat (often popularly called "black light"), and detecting the target on a screen. This is precisely like radar but using EM radiation of a shorter wavelength. So far as the author knows, no anti-aircraft defence system today works on this principle, though the emergence of stealth aircraft is likely to cause renewed interest.

Instead, all today's IR technology for use against aircraft appears to be devoted to the development of purely passive (non-emitting) devices fitted in the noses of missiles in order to enable them to home on the heat of their target. There are masses of different materials which are highly sensitive to IR radiation. When heat rays fall on these materials the radiation knocks electrons out of one atomic band into another, which is the same thing as saying a small electric current is generated. This current is then amplified and used to control the missile guidance system.

The different IR detector cells are each sensitive to a particular spread of wavelengths; for example cadmium mercury telluride responds most strongly to a wavelength of about 10.6 microns, which is equivalent to a dull red heat. Almost all detector materials at present in use work much better—many thousands of times better—if they are refrigerated to an extremely low temperature. This cuts out most of the background "noise" and enables them to spot even a very faint heat source clearly. Early IR devices were relatively crude and unreliable. They could easily be distracted by the sun, or by sunlight reflected in a river or greenhouses, and for a sure lock-on to a target the latter needed to have an operating afterburner seen from astern. Today IR missiles exist which can lock-on to a target from any aspect, even head-on, and can unerringly detect even the insignificant IR plume from a small helicopter.

This underlines the difficulty of making a power-

ful jet bomber invisible to sensitive IR detectors. Such aircraft can pump out heat at the rate of about 1,000 megawatts, similar to the generating capacity of a major power station (electric utility). There is no way that this heat output can be eliminated or even signficantly reduced; it is a fundamental consequence of the propulsion task needed to move the bomber through the dense low-level atmosphere at about Mach 0.92. So what we have to do is try to dilute the heat source with cool air and shroud the engine installation so that no hot parts can be seen directly. As noted earlier, this is almost the same as trying to make the aircraft invisible to radar and too quiet to be heard; to a considerable degree a design solution that answers one problem goes a long way to solving others.

No more afterburners!

The first thing we have to do is throw away afterburners. Most of today's combat aircraft have augmented turbofan engines with extra fuel burned in the bypass air and in the core flow downstream of the turbines. This extra fuel is used only for takeoff and for high-speed dashes across heavily defended targets, and at the cost of an enormous increase in fuel consumption it can boost the thrust of the engine by from 50 to 100 per cent. To a stealth aircraft it means a total abandonment of everything that has been striven for, because an operating afterburner raises the temperature of the jet to perhaps 1,800°C, equivalent to a bright white heat, and it also raises the speed of the jet to far beyond that of sound. The jet itself becomes an incandescent flame for a considerable distance downstream, with brilliant "shock diamonds" visible in the jet caused by reflections of the shockwaves from the periphery where the jet meets the still atmosphere. Noise is excruciating.

Nothing more totally un-stealthy could possibly be imagined. So completely does the afterburner negate stealth design that both it and PCB (plenum-chamber burning, which is a kind of afterburning for jet-lift aircraft of Harrier type) will in the author's opinion have to be omitted from all future stealth warplanes. After all, it is better to fly more gently and survive than to blast through the sky and invite destruction.

In fact, we have to go very much further than merely leave off all forms of reheat or afterburning. We have to bury our engines deep inside wing or fuselage and go to what may seem unreasonable lengths to make the jet from each engine induce cool surrounding air. This air serves the dual function of reducing IR emission and reducing noise. What comes out at the back is not very different from the mixed jet flow from a modern airline HBPR engine,

Below: A US Navy F-14A is catapulted off *Saratoga* with both engines in full 'burner. Thrilling to viewers of *Top Gun*, such a propulsion system could mean death in actual warfare.



as mentioned earlier in this chapter, but the basic engine of the warplane needs to have a lower BPR, typically somewhere near 1.5 to 2. When the induced airflow is taken into account the overall BPR of the installed engine might be nearer to 6 or even 10. To induce so great a flow we have to turn our jet nozzle into an efficient injector-type pump, by splitting the jet up into a number of smaller jets spaced around a giant surrounding jetpipe. It is essential to lose as little efficiency as possible in doing this in order not to degrade the aircraft's range with a given weapon payload.

Cooling the nozzle

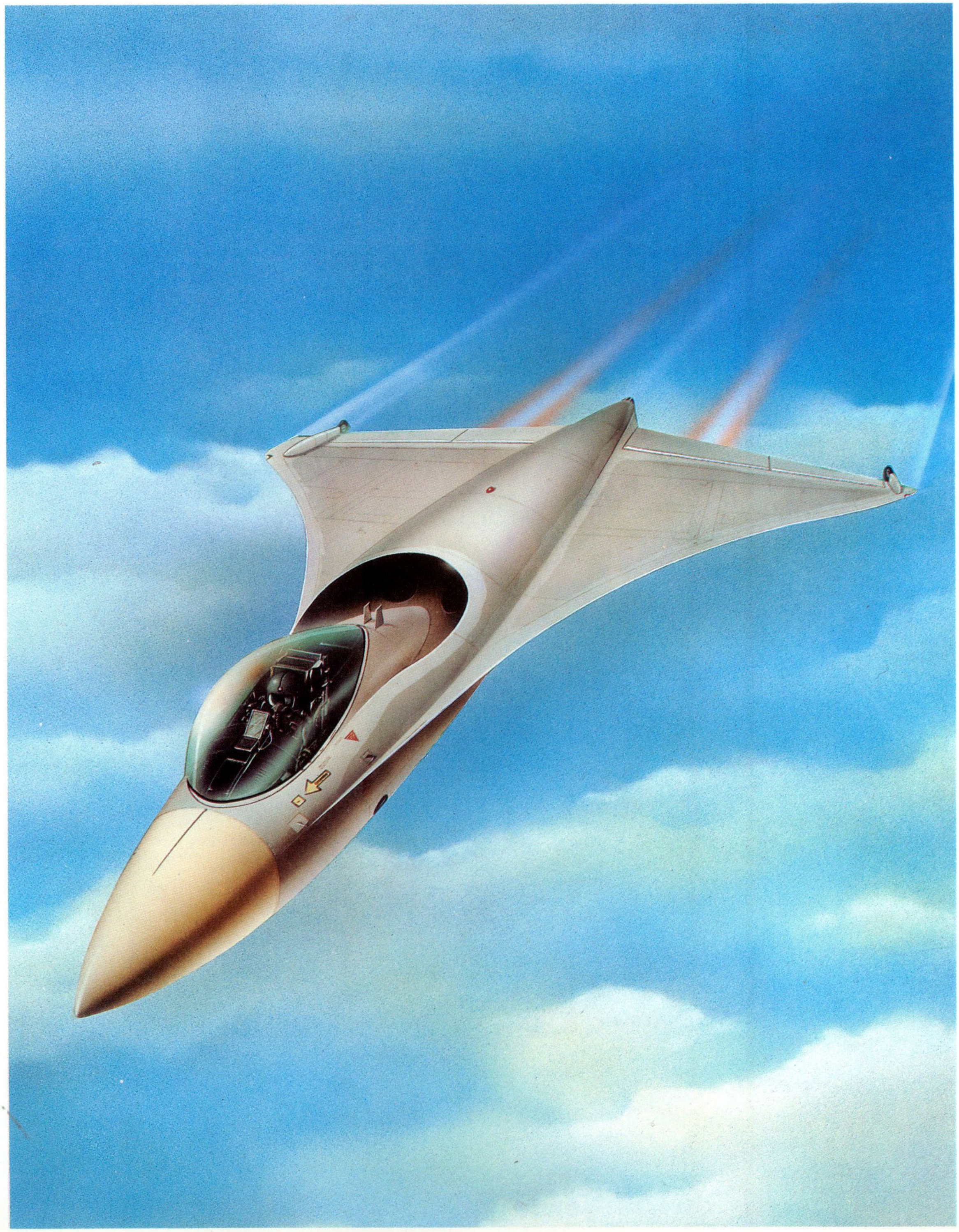
The big surrounding jetpipe has to be continued well downstream of the jet nozzle system of each engine, in order to prevent an enemy IR detector from "seeing" any metal or other material sufficiently hot to trigger a response. Thus, to meet our objective we hide the engine itself away in between a large inlet system and large nozzle system, and make it surround itself with a very large flow of cold fresh air. What comes out at the back is a huge jet with a modest mean velocity and an even more modest mean temperature, possibly no more than about 300°C even at full throttle.

Most of the unofficial reports claiming to describe the existing stealth aircraft built by Lockheed and Northrop have stated that fins (vertical stabilizers) are arranged on each side outboard of the jet nozzles. As fins do not appear essential from the stability and control viewpoint, it may be that they are judged worth having because of their ability to shield the engine nozzles from IR detection from the side, though this remains pure speculation.

What is uncertain is whether a true stealth aircraft can be supersonic. The Lockheed CSIRS is said to be capable of cruising at Mach 2, but the author finds this difficult to believe. Such a speed demands a very much greater mean jet velocity, and a much higher mean jet temperature, than any stealth aircraft could consider for a moment. Moreover, as explained in the next chapter, why dash along at Mach 2 if nobody knows you are there?

Below: A 1985 sketch by a Lockheed artist of an Advanced Tactical Fighter, showing various low-observable features. A year later Lockheed began building a real ATF, the YF-22A.





Above: In the author's opinion future combat aircraft must be not only stealthy but also STOVL designs not tied to vulnerable airfields. This suggestion has a Pegasus-type vectored engine and powerful bleed-air reaction-jet controls.

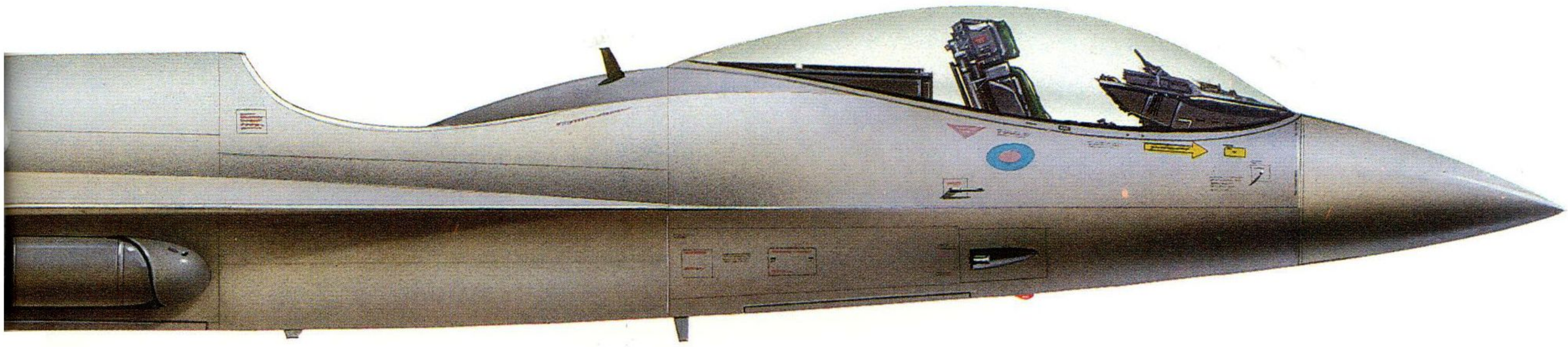
Above: To survive in any future war between the Superpowers, aircraft must be of stealth design and never go near a known airfield. Such an aircraft is depicted here, with minimal RCS, cool and quiet vectored-thrust engine nozzles and tail reaction valves instead of a vertical fin and rudder.

Above: Looking down on this quiet STOVL aircraft the only undesirable feature is the large canopy. This could be replaced by a totally synthetic all-weather cockpit.

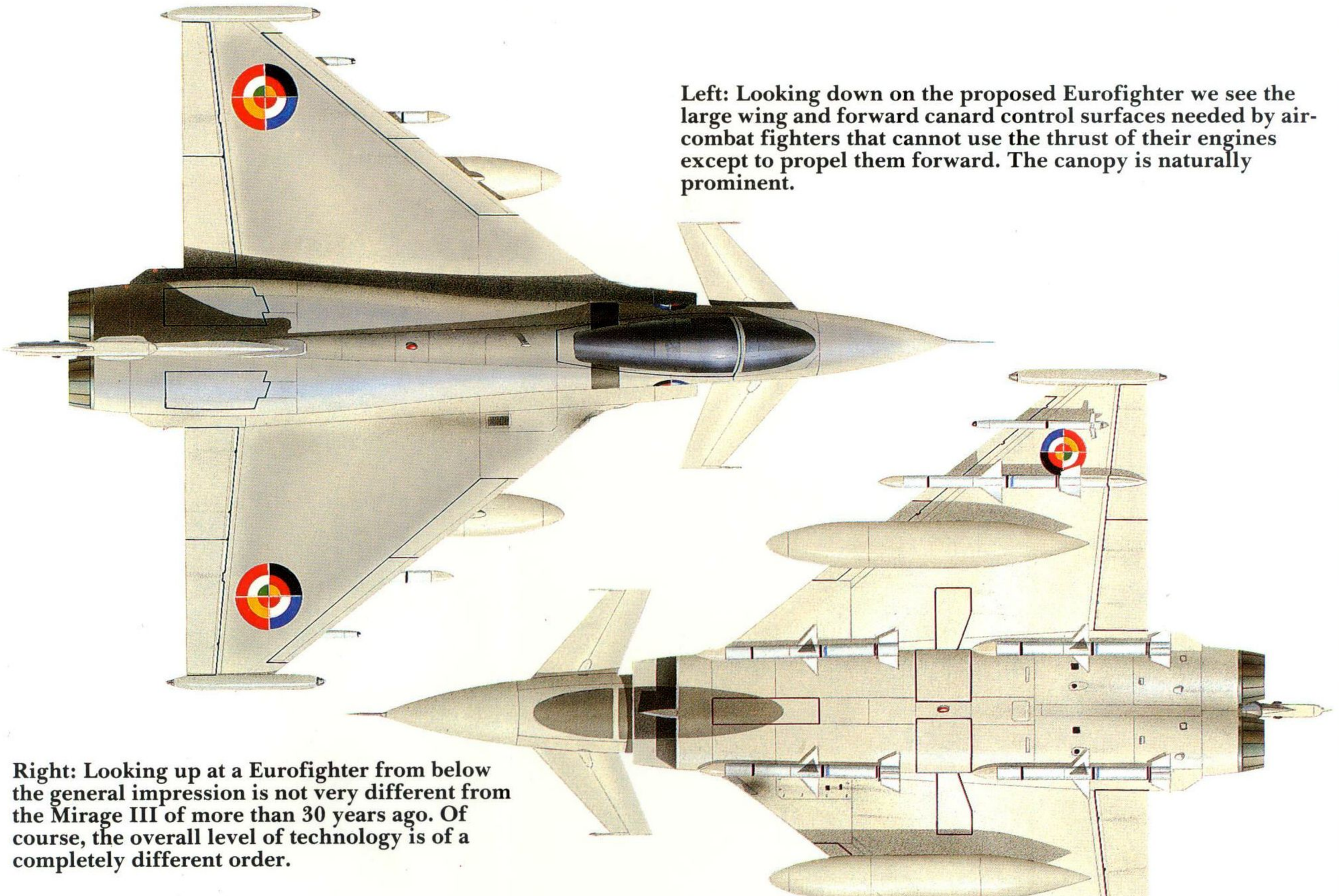
Above: Seen from below the quiet stealth STOVL blends against the sky. All weapons would be carried internally, in a bay which could alternatively carry recon sensors.

EFA

EuroFighter



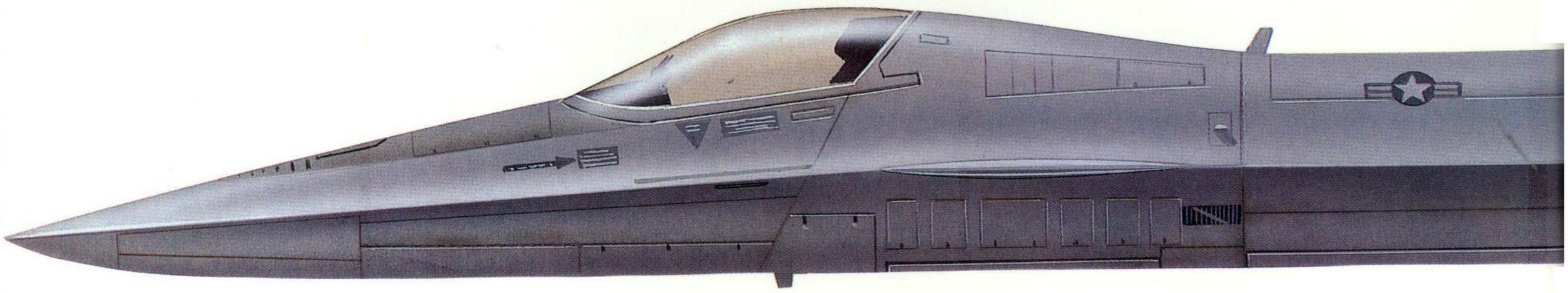
Left: Looking down on the proposed Eurofighter we see the large wing and forward canard control surfaces needed by air-combat fighters that cannot use the thrust of their engines except to propel them forward. The canopy is naturally prominent.



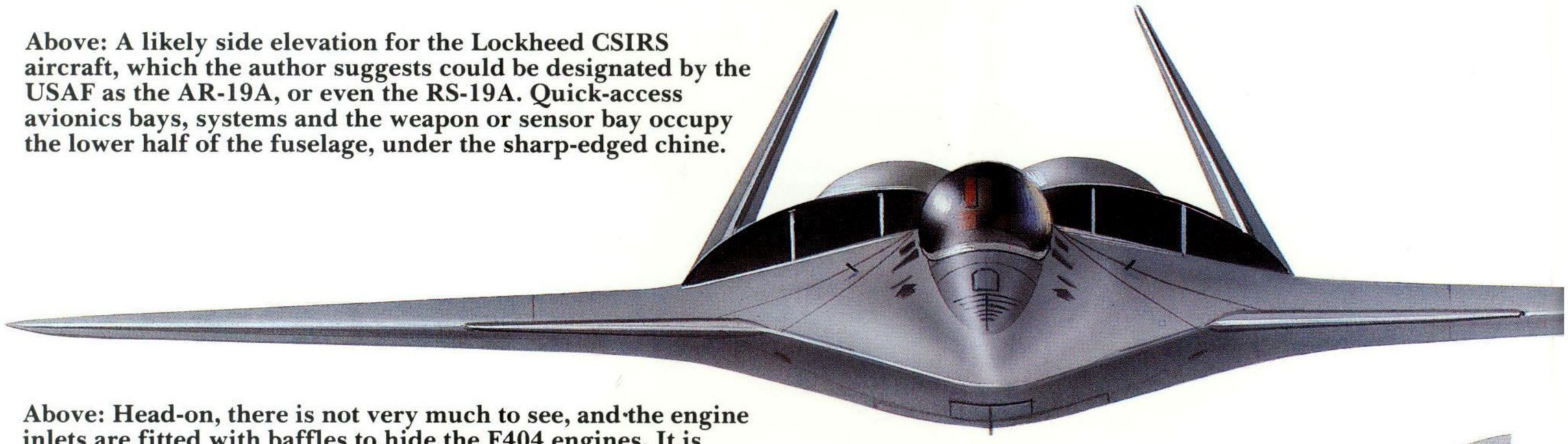
Right: Looking up at a Eurofighter from below the general impression is not very different from the Mirage III of more than 30 years ago. Of course, the overall level of technology is of a completely different order.



Above: Side elevation of the proposed EFA (European Fighter Aircraft). This is being designed in the full knowledge of low-observables technology, and is said to apply this technology "extensively" though it seems to make only a token attempt to reduce aural and IR signatures. Moreover, it would always be tied to airfields of known location, like virtually all other new Western fighters.



Above: A likely side elevation for the Lockheed CSIRS aircraft, which the author suggests could be designated by the USAF as the AR-19A, or even the RS-19A. Quick-access avionics bays, systems and the weapon or sensor bay occupy the lower half of the fuselage, under the sharp-edged chine.

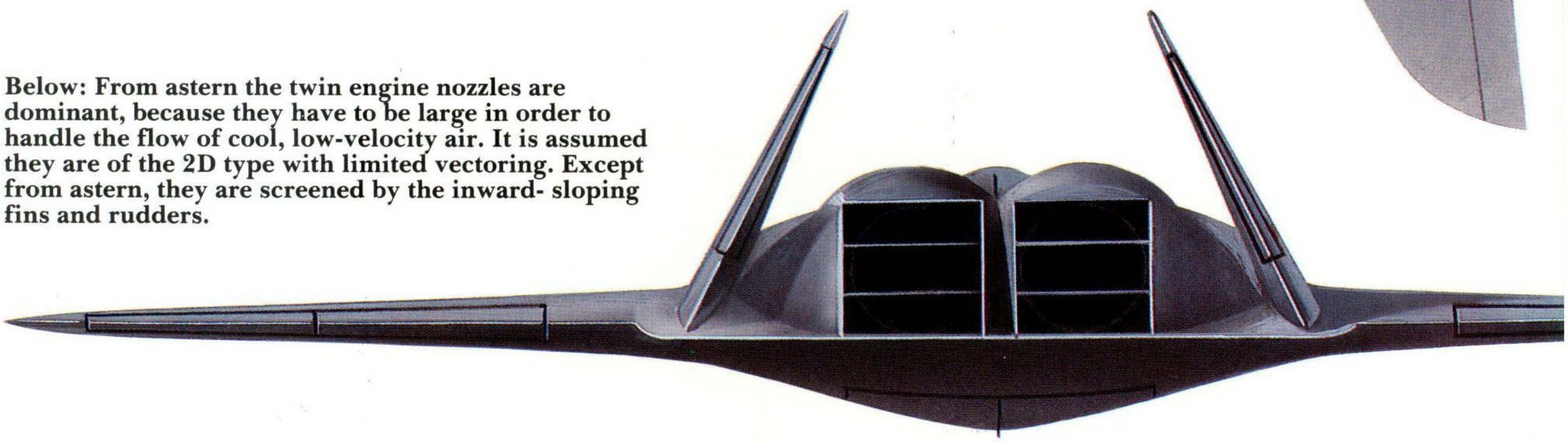


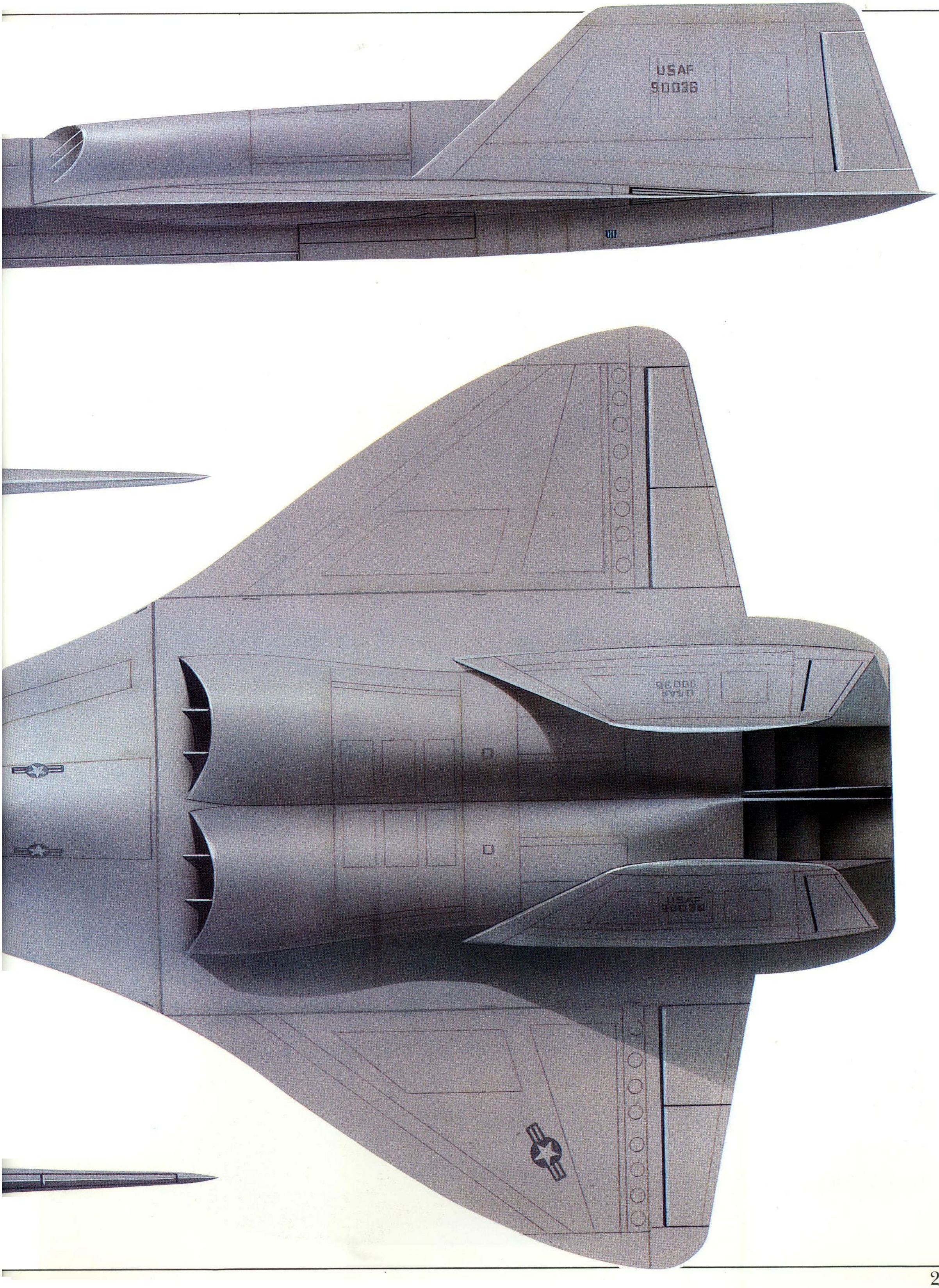
Above: Head-on, there is not very much to see, and the engine inlets are fitted with baffles to hide the F404 engines. It is assumed that a conventional canopy is retained, and that (as in the F-16) moulded polycarbonate resists birdstrikes.

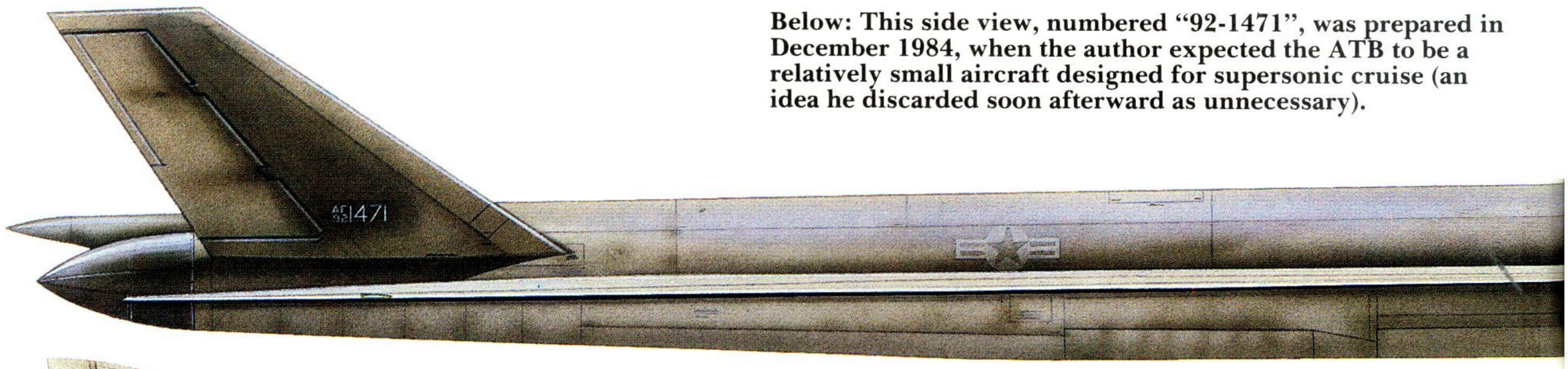
Right: In plan view the Lockheed has been likened to a Shuttle Orbiter, through it is very much smaller and has foreplanes. An inflight-refuelling receptacle is shown ahead of the cockpit, and the outer wings fold to enable global deployment of the CSIRS to be made by air cargo aboard USAF C-5s.



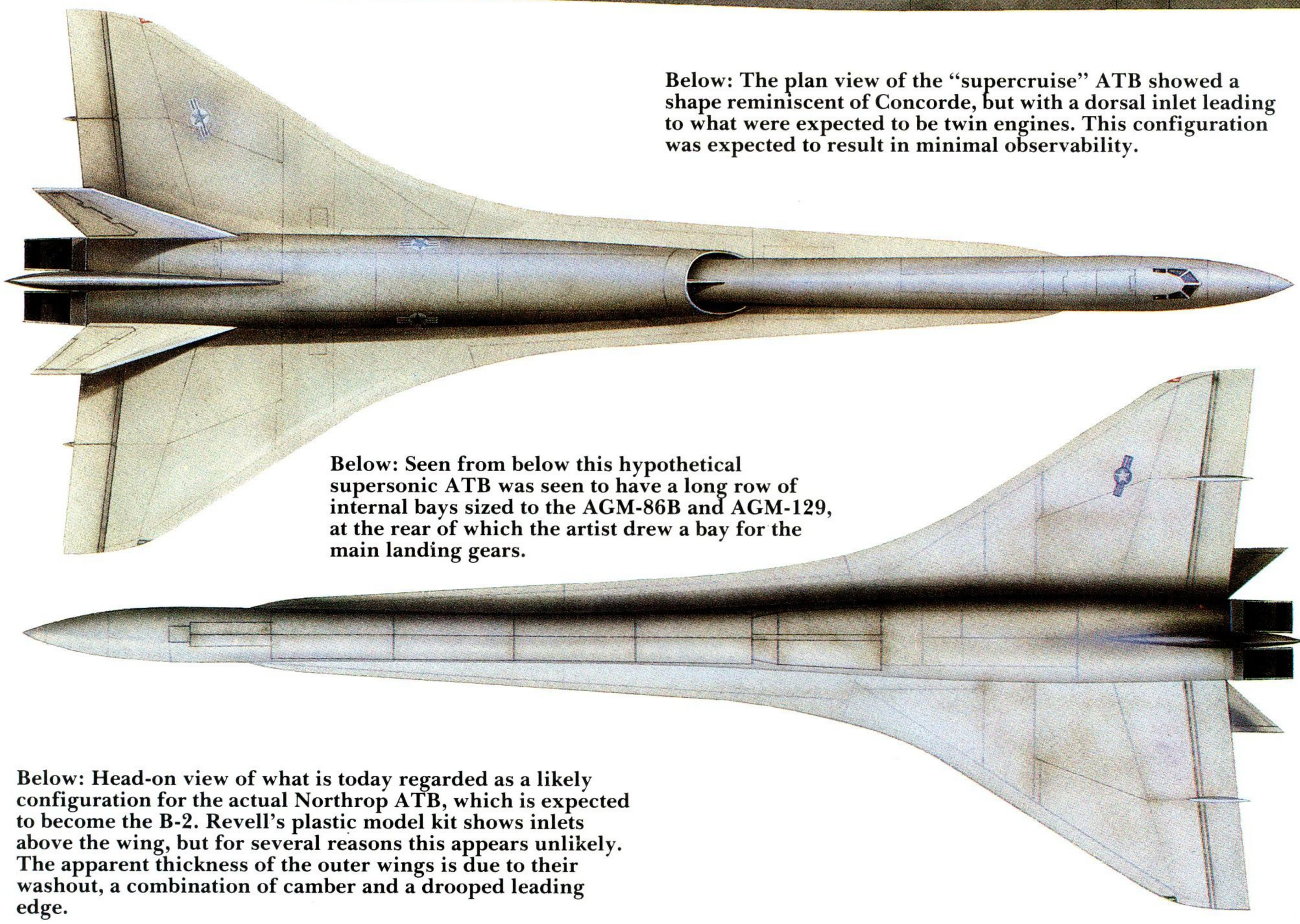
Below: From astern the twin engine nozzles are dominant, because they have to be large in order to handle the flow of cool, low-velocity air. It is assumed they are of the 2D type with limited vectoring. Except from astern, they are screened by the inward- sloping fins and rudders.




USAF
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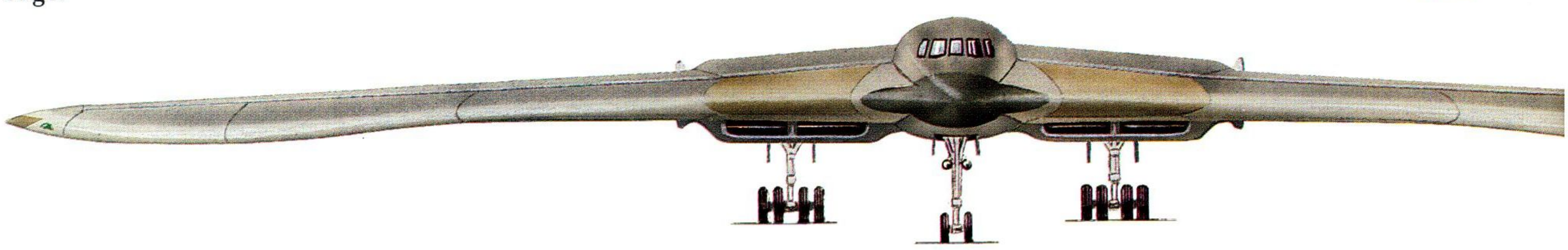
Below: This side view, numbered "92-1471", was prepared in December 1984, when the author expected the ATB to be a relatively small aircraft designed for supersonic cruise (an idea he discarded soon afterward as unnecessary).



Below: The plan view of the "supercruise" ATB showed a shape reminiscent of Concorde, but with a dorsal inlet leading to what were expected to be twin engines. This configuration was expected to result in minimal observability.

Below: Seen from below this hypothetical supersonic ATB was seen to have a long row of internal bays sized to the AGM-86B and AGM-129, at the rear of which the artist drew a bay for the main landing gears.

Below: Head-on view of what is today regarded as a likely configuration for the actual Northrop ATB, which is expected to become the B-2. Revell's plastic model kit shows inlets above the wing, but for several reasons this appears unlikely. The apparent thickness of the outer wings is due to their washout, a combination of camber and a drooped leading edge.

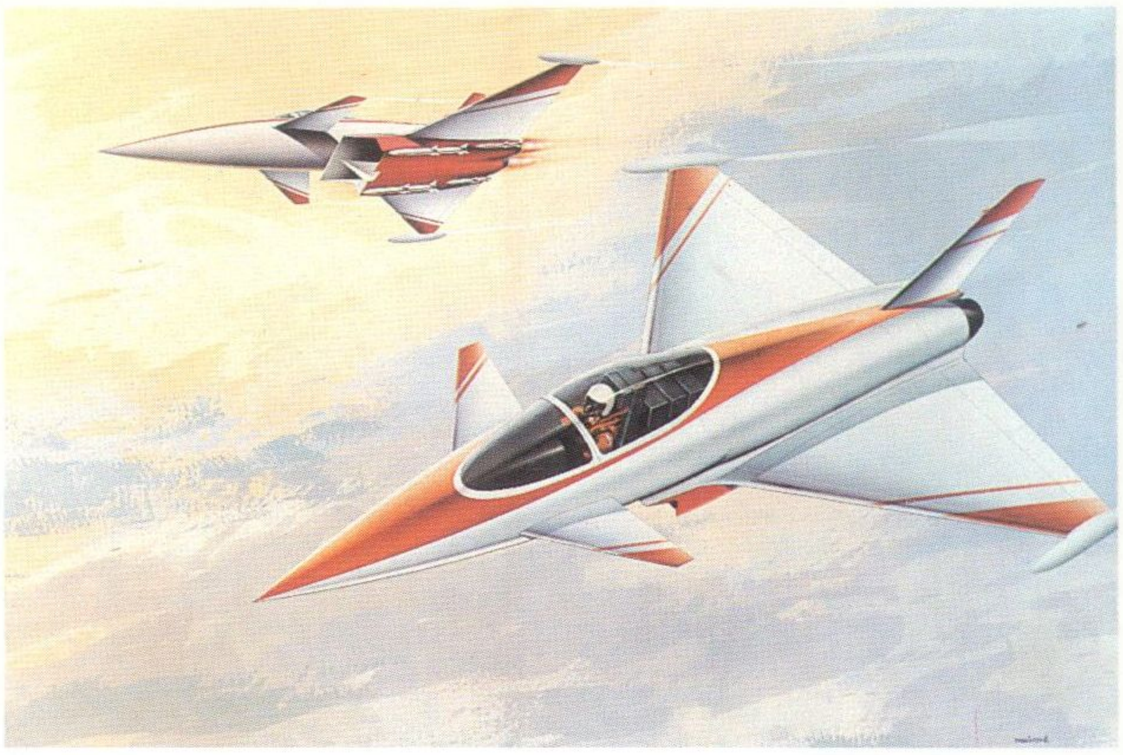






Right: Plan view of how the team which prepared this book envisage the forthcoming ATB. An obviously subsonic aircraft, it has several strong similarities to the British Vulcan, though of course these are only superficial. In fact the new Northrop is probably the most challenging and fascinating example of the aircraft designer's art yet built. Perhaps its chief shortcoming is that SAC demanded such a large combat radius that the ATB is as big and powerful as the B-1B, and this makes it easier to detect, expecially by IR.

Below: Side elevation of the "Northrop B-2" as envisaged by the author and artists. 2D vertically vectoring nozzles are suggested for the four unaugmented F101 engines, whose jets are surrounded by induced cold air. In practice the national insignia and other stencilling would probably be much less obvious.

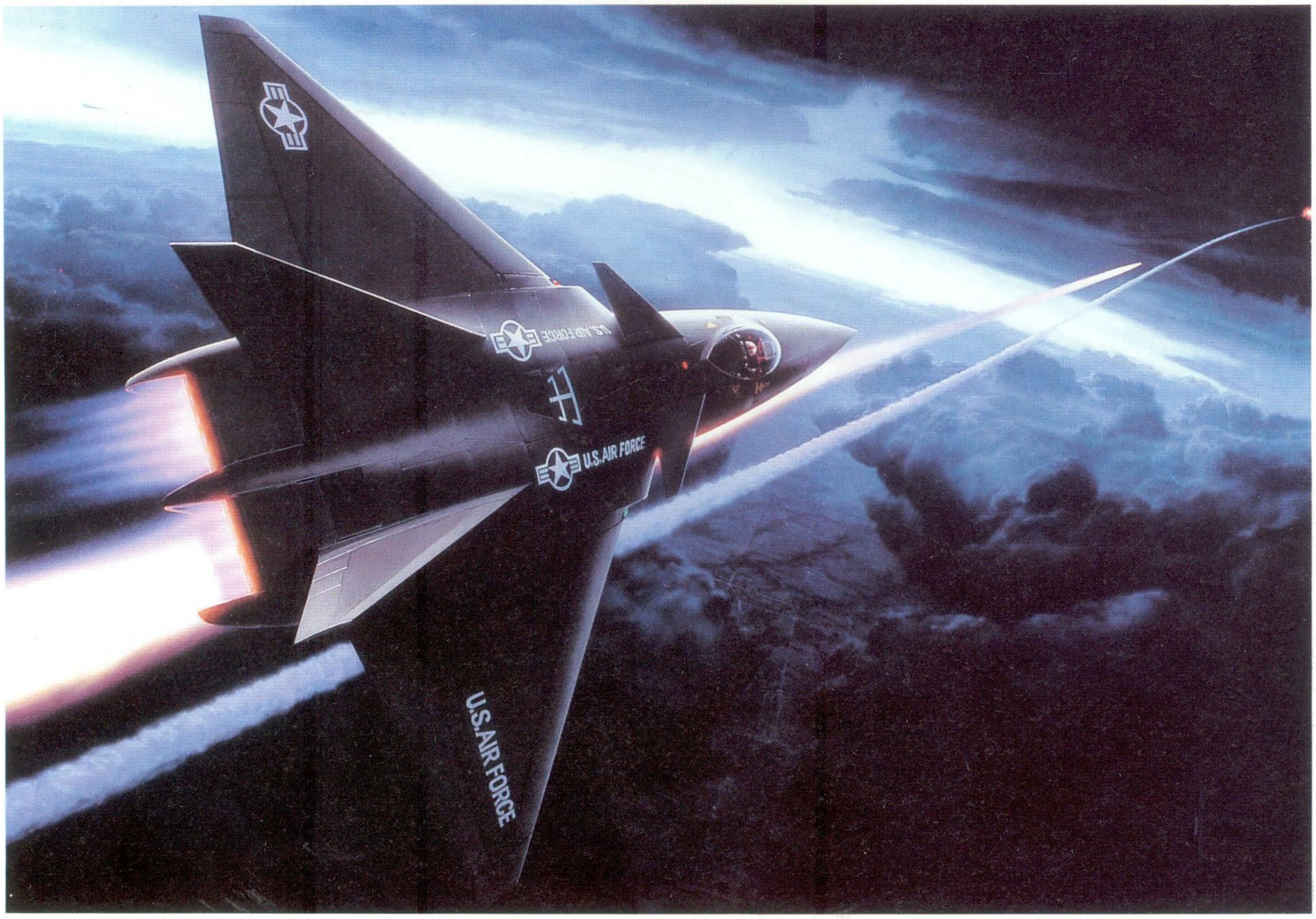


Above: An MBB artist's impression of the Jagdflugzeug 90, a predecessor of the definitive EFA. Though stealth was a buzz-word when this was sketched, nothing was done at that time to make the inlet duct less observable.



Right: In contrast, today's EFA is shown (in this case by a BAe artist) with an engine inlet and duct carefully shaped to reduce radar reflectivity. Missiles are as conformal as possible, and the aircraft is painted pale grey.

Below: In October 1986 Lockheed, which is actually building the YF-22A Advanced Tactical Fighter, issued this sketch of a suggested ATF. Supersonic cruise with white-hot afterburners seems a curious way to remain undected.



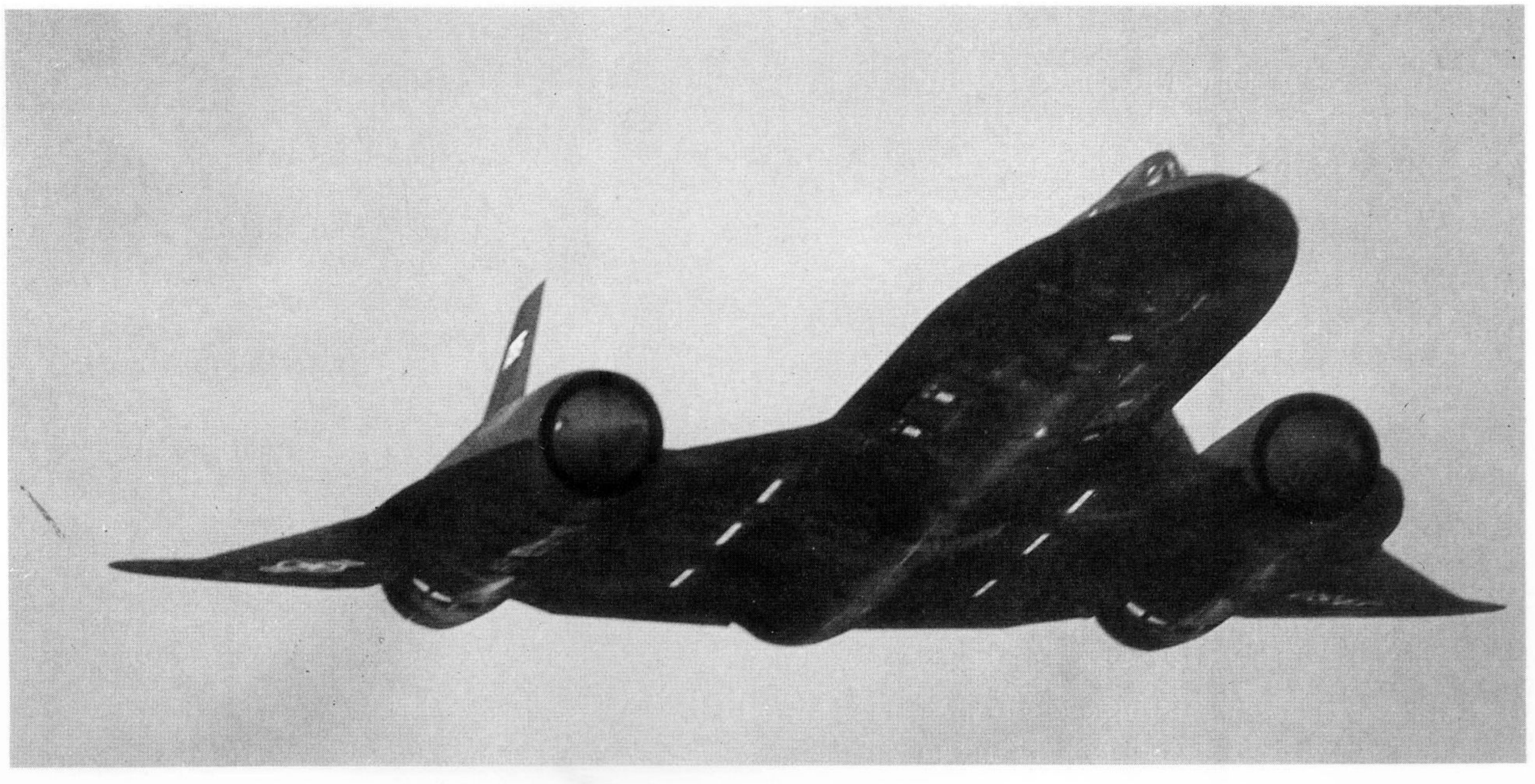
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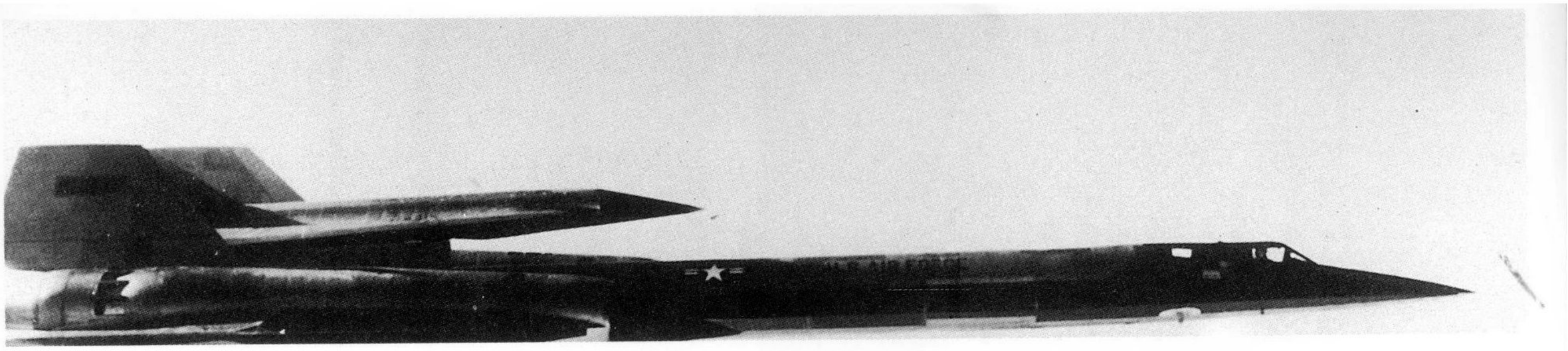
The Lockheed Concept

THE WORLD'S FIRST stealth warplane is a product of the mighty Lockheed Corporation. It was created in that organization's so-called "Skunk Works", the highly secure and brilliantly talented facility at Burbank, California, which was founded and for almost 30 years run by Clarence L. "Kelly" Johnson. Among the better-known aircraft to emerge from this secret plant were the U-2 and its successors and the A-12/YF-12A/SR-71 Blackbird family. The first followed the philosophy of flying so high that it could not be shot down. The second followed the philosphy of flying even higher, and at so high a speed that it could not be shot down. But by 1970 it was beginning to look as if the deployment by the Soviet Union of ever-better SAM systems was going to make life hazardous for all aircraft—unless they could remain undetected.

Below: Lockheed's amazing SR-71A incorporates everything known about stealth technology in 1962-63. Both the external shape and underlying structure were designed to minimize RCS, and ferrite-ball paint was used for the first time.

The primary mission of the U-2 and SR-71 has always been reconnaissance, gathering information by overflying enemy territory. By the 1960s so-called "spy satellites" had begun to inject a wholly new range of possibilities into the non-stop reconnaissance ball-game, which is the most important of man's warlike activities that goes on "for real" even in the absence of war. It is a serious business, and in the 1950s many American warplanes engaged in optical and, especially, in Elint reconnaissance missions over Communist territory or sea areas were actually shot down. Nobody will forget that on May Day 1960 a CIA-operated Lockheed U-2 was brought down by a SAM over Sverdlovsk, in the heart of the Soviet Union. Satellites thereafter replaced aeroplanes for such strategic overflights, but they pass over their target areas at so great a height that even the fantastic Big Bird and KH (Key Hole) series of satellites—also largely Lockheed products—cannot achieve the picture resolution of sensors carried in aircraft.





Above: Hair-raising trials were flown with the Lockheed D-21 stealth reconnaissance drone, launched from a pick-a-back position on a Lockheed A-12. The D-21 combined the speed of the SR-71A with a considerably smaller RCS.

There has therefore been a continuing requirement for aircraft capable of surviving reconnaissance missions through hostile airspace, and if the traditional answers of speed and altitude no longer worked, there appeared to be only one alternative: to avoid being detected. From the outset this was obviously a gigantic challenge, but it did not take any particularly great intelligence to see that this was before long going to be a requirement not just of reconnaissance aircraft but of *all* military aircraft. The technology of low observability, popularly known as stealth, thus became a top priority in the design of US warplanes, and also a highly classified one.

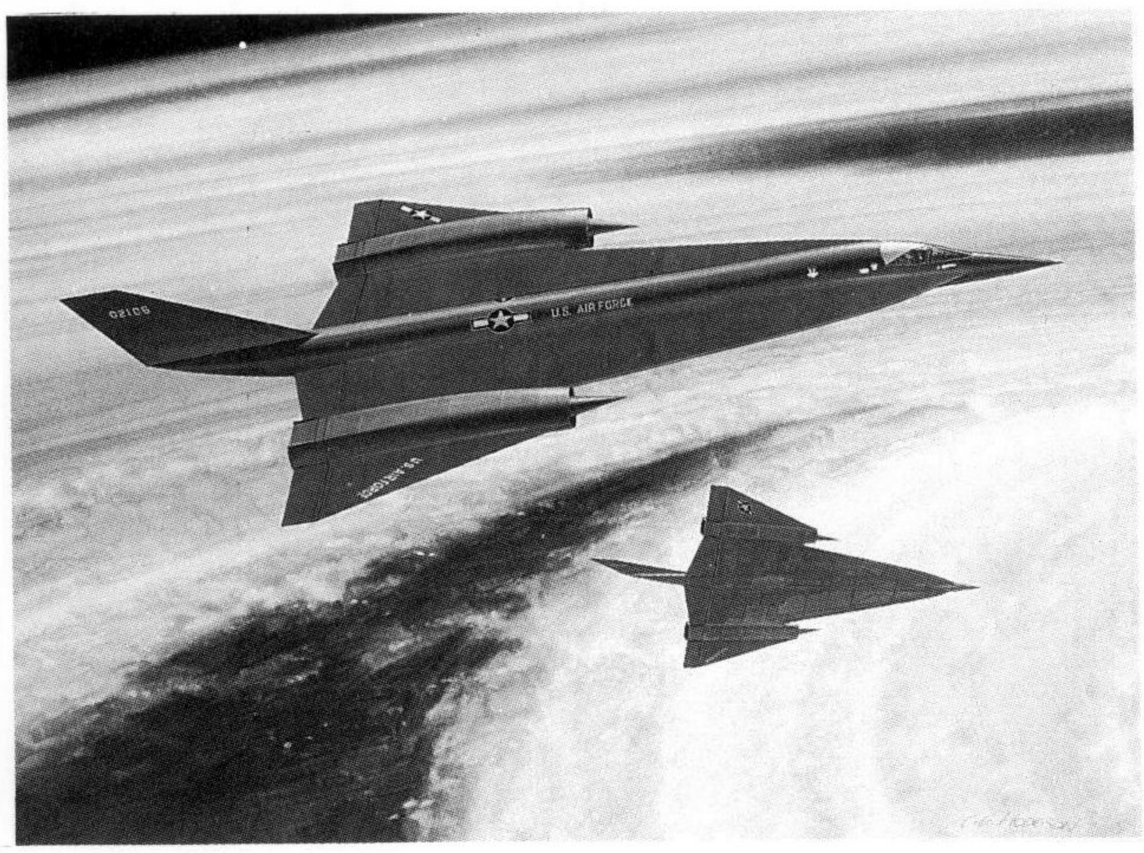
DARPA stealth programmes

So far as the published record goes, the first thing that happened was that in 1973 DARPA, the US Defense Advanced Research Projects Agency, an organization of the Department of Defense, launched a major research programme called Have Blue. It quickly involved extensive laboratory research to do what any sensible person might have thought would have been started in 1936: to find out how aircraft should be designed so as to be difficult to see, to see on radar, to detect on IR wavelengths, and to hear. In order to get some practical experience the USAF bought a simple light aircraft, a Windecker AC-7 Eagle 1, and played about with it. This aircraft, a neat low-wing four-seater with a 285hp engine, was selected because its airframe was made almost entirely of GRP (glassfibre reinforced plastics), and it was of very clean aerodynamic design. Dr Leo Windecker called the structural material Fibaloy, and its extremely low radar signature was further improved after the USAF interest became apparent.

The military designation for the Eagle 1 was YE-5, E being the symbol for a US aircraft with a "special electronic installation". In this case no special equipment was carried, but the purpose of the aircraft was to see how far it could be made invisible to ground surveillance or fighter radars. Various modifications were made both to the external shape and to the underlying structure, propeller and various other items. Results were encouraging.

By 1974 the Have Blue programme had provided enough information for the USAF to issue RFPs (requests for proposals) for a much more advanced proof-of-concept aircraft, known as the XST (Experimental Stealth Technology). This was to be a fast jet, incorporating every known technique to remain completely silent and invisible to all known detection systems even at ranges of less than a mile. Four impressive responses were received, and following exhaustive evaluation of the submissions by Grumman and Lockheed the latter company's proposal was accepted in 1976. A USAF/DARPA contract was signed for five XST aircraft. These, it must

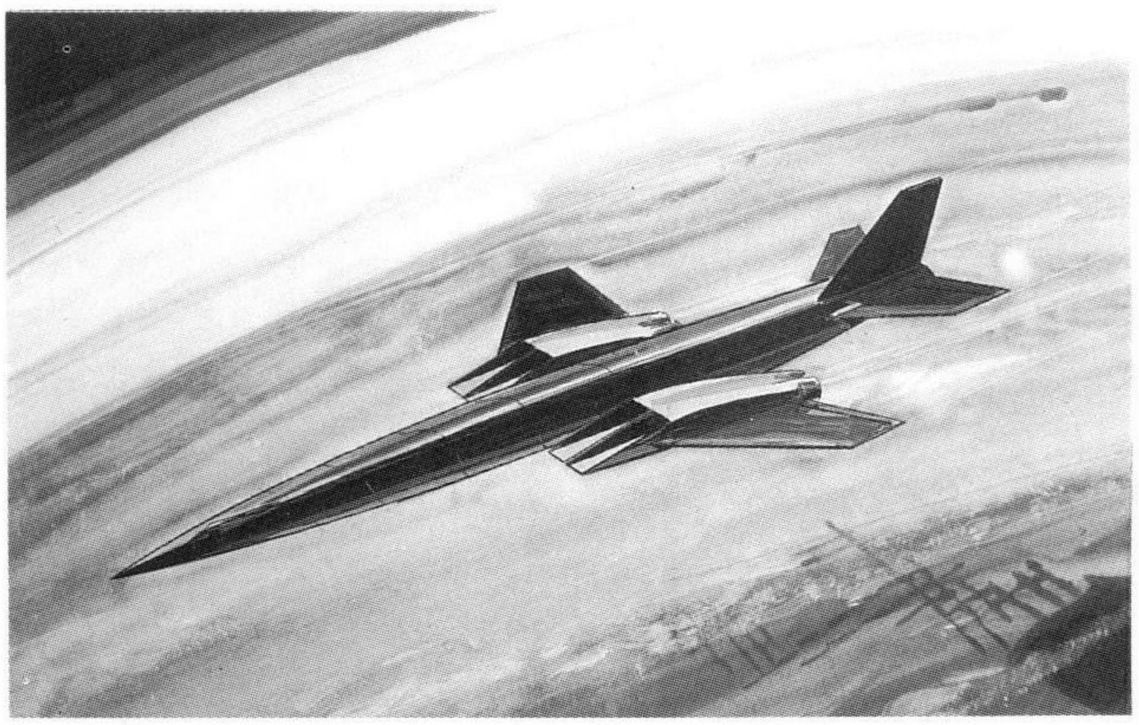
Below: This drawing of a supersonic-cruise fighter was put out by Lockheed-California in 1980. Apart from the vectored methane-burning engines it featured several stealth qualities. But supersonic speed implies high observability.



be emphasized, were not to be prototypes of an eventual production machine, but research platforms intended to show exactly how such a production aircraft should be designed.

The Skunk Works had already got to work; indeed it had been investigating low-observables technology ever since design work on the SR-71 had tapered off in the mid-1960s. Johnson remained as consultant, able to oversee the entire programme, but by this time the ADP (Advanced Development Projects) facility was being run by Ben Rich, a brilliant aerodynamicist and thermodynamicist who had been a key figure from the start of the U-2. So important did "stealth" appear that it was decided to restructure the old Skunk Works, and in 1984 a new company, Lockheed Advanced Aeronautics Co, was formed with Rich as President. This has a 2,000-strong laboratory and works at Rye Canyon (Valencia), called the Kelly Johnson Research and Development Center, and also manages equally large facili-

Below: Another Lockheed proposal of about 1980 for a supersonic cruise aircraft, blasting out highly visible and audible jets, yet with "inverted" engine inlets specially designed for stealth reasons. To the author this is pointless.



Below: The desperate vulnerability of aircraft on airfields prompted this Lockheed proposal for hydroski-equipped warplane able to operate from rivers and canals. Again, several of its features were designed for stealth qualities.

ties at Burbank and at Marietta, Georgia. Soon there was so much going on that it is remarkable how little leaked into the ever-alert media.

One of the first events that might have been noticed was the arrival at Burbank in 1977 of a USAF C-5A. It took on a load at night and departed for an unstated destination (the flight plan probably was logged at Burbank as Nellis AFB). Where it actually went was the same airstrip as had been used for early testing of the previous secret Lockheeds: variously known as Area 58, Groom Lake or Tonopah Test Range, it lies south of Bald Mountain, Nevada, about 100 miles (160km) north-west of Nellis, which is close to Las Vegas. Between five and seven XSTs were built, at least one being a structural and fatigue test specimen which confirmed that airframes made mainly of composite material have an indefinite fatigue life.

Nothing so far has been officially published about the XSTs, but they are unofficially said to look like rather flattened versions of the Shuttle Orbiter, much smaller—span about 18ft (5.49m), length about 35ft (10.67m)—and to fly at about Mach 0.9 on two General Electric CJ610 turbojets of about

Below: The latest (October 1985) artwork from Lockheed to show features of a stealthy Advanced Tactical Fighter. In the author's view there is no point in building a stealth aircraft then parking it on an airfield known to the enemy.



3,000lb (1361kg) thrust each. These are civil non-afterburning versions of the J85 turbojet as used in the Northrop F-5. Choice of a turbojet rather than a turbofan was instructive. It showed that, rather than use a large-diameter HBPR fan engine, the optimum results appeared to be gained by burying a slim turbojet deep inside the aircraft and making it induce a large surrounding flow of cold and relatively quiet air. It is said that two XSTs were lost in crashes, for reasons not connected with the stealth features, but that on the whole they demonstrated "superbly" that they could be made virtually undectable by any available means even at quite close ranges.

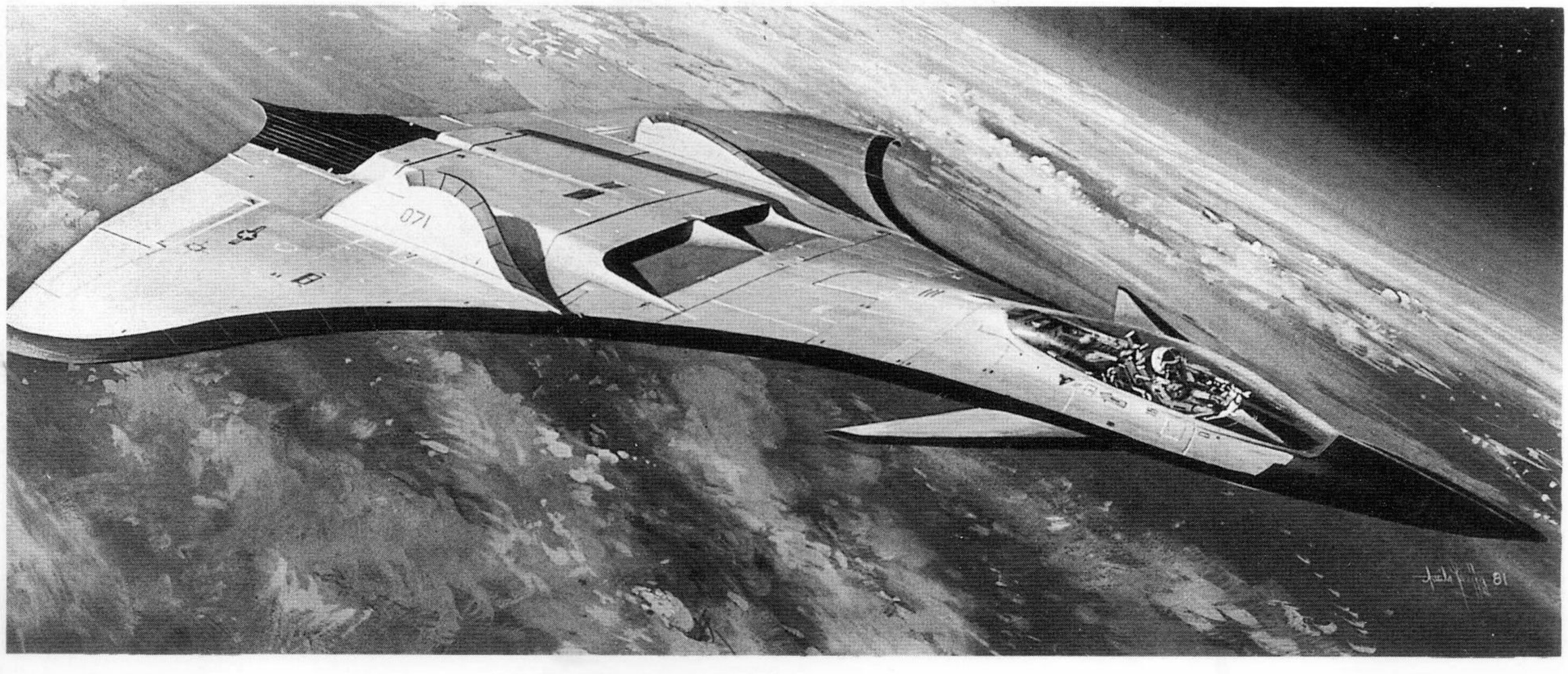
At the same time it is believed that Lockheed Missiles & Space Co developed under USAF/DARPA contract a test vehicle for an advanced cruise missile. This is clearly a much easier task, because of its smaller size and IR signature, and there seems no reason to doubt that such missiles can be made totally undetectable. The LMSC test vehicles are said to have flown from B-52 carrier aircraft operating from Edwards AFB. Today General Dynamics is prime contractor for a totally new ACM (Advanced Cruise Missile) of wholly stealth design. Powered by a Williams F112 engine, itself designed for near-zero noise and IR signatures when installed in the missile, this weapon is expected to have a range of at least 1,500nm (1,725 miles, 2776km) with better targeting accuracy than today's AGM-86B. It has been under development, with Lockheed's help, since April 1983.

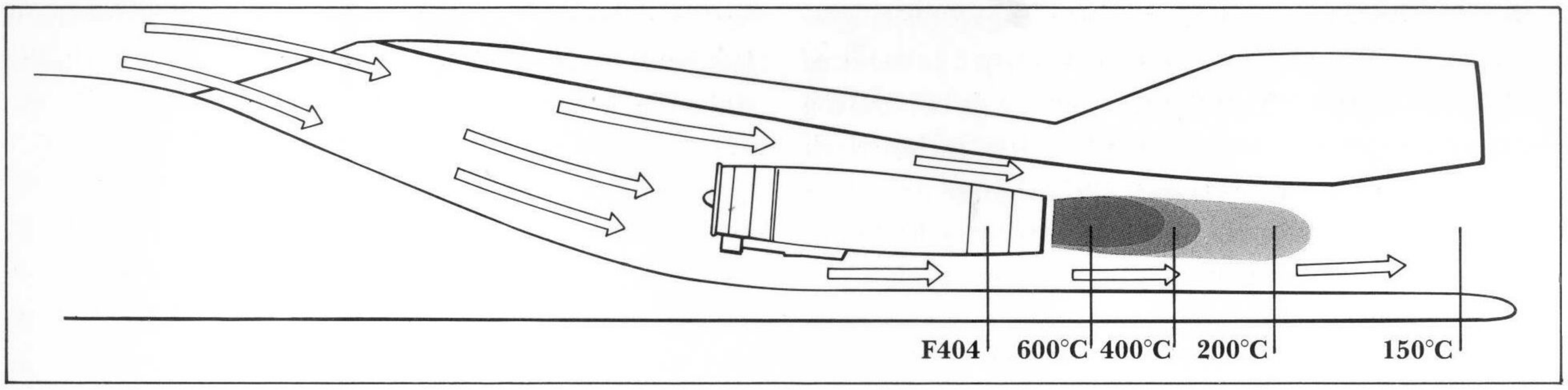
Below: The first attempt (1981) by an American artist to portray a stealthy Advanced Tactical Fighter. In a real aircraft the sloping fins would be right at the back, where they could mask the hot structure downstream of the engines.

An official disclosure

In 1980 the Defense Department said "This so-called 'stealth' technology enables the US to build manned and unmanned aircraft that cannot be successfully intercepted with existing defence systems. We have demonstrated to our satisfaction that the technology works. It promises to add a unique dimension to our tactical and deterrent strength. At the same time it will provide us the capabilities that are wholly consistent with our pursuit of wholly verifiable arms-control agreements". What the official did not say was that his department had set in train machinery that was to make available several billion dollars for stealth aircraft, without such aircraft appearing (yet) in the USAF budget.

The first of these aircraft was officially called the CSIRS, for Covert Survivable In-weather Reconnaissance Strike, which precisely states its mission. Unfortunately it has been reported almost everywhere as the F-19, or F-19A, because 19 is the missing number in the sequence alotted to US fighters. The USAF has officially stated that there is no such aircraft, and this is true, but that is because the prefix letter is actually not F. It is probably RA, or AR, for the missions of reconnaissance and attack. Whether it is RA-19A or AR-19A, or something else yet again, it not only does exist but it exists in numbers and has for some years been in regular





Above: This is the kind of installation of non-afterburning F404 engines we may expect to see eventually in the Lockheed recon/strike aircraft. In the author's opinion stealthy propulsion systems are incompatible with supersonic speeds.

USAF service, Indeed, surprisingly, it has been reported from theatres outside the United States.

This mysterious aircraft is also said to be known as the Ghost or Specter. In shape it follows the configuration of the XST, though on a larger scale of size. Span is said to be in the region of 35ft (10.67m) and length about 55ft (16.76m), and takeoff weight is thought to be about 30,000lb (13,608kg). The engines are confirmed as two General Electric F404 turbofans, of the type in wide use in the F/A-18 Hornet. This is a turbofan of low BPR (only 0.34), and in the F/A-18 it is fully augmented so that in full 'burner it gives a thrust of 16,000lb (7258kg). Many jumped to the conclusion that such engines power the Lockheed CSIRS, but obviously afterburners cannot be fitted and a more likely thrust for each engine is about 11,000lb (4990kg). They lie side-by-side in an installation of the kind outlined in previous chapters, fed through cleverly designed inlets in the upper surface of the squashed-looking airframe.

There is little doubt that this aircraft owes something to the SR-71, though that much larger machine is made of titanium, flies at Mach 3 and is seen by most defense systems from below. The CSIRS is made of many composite materials, including modified Fibaloy, almost certainly flies at high-

Below: Today's Saab J35F Draken inherited various stealth qualities from the remarkable Saab 210 of 1952 – before low-observables technology had been thought of.



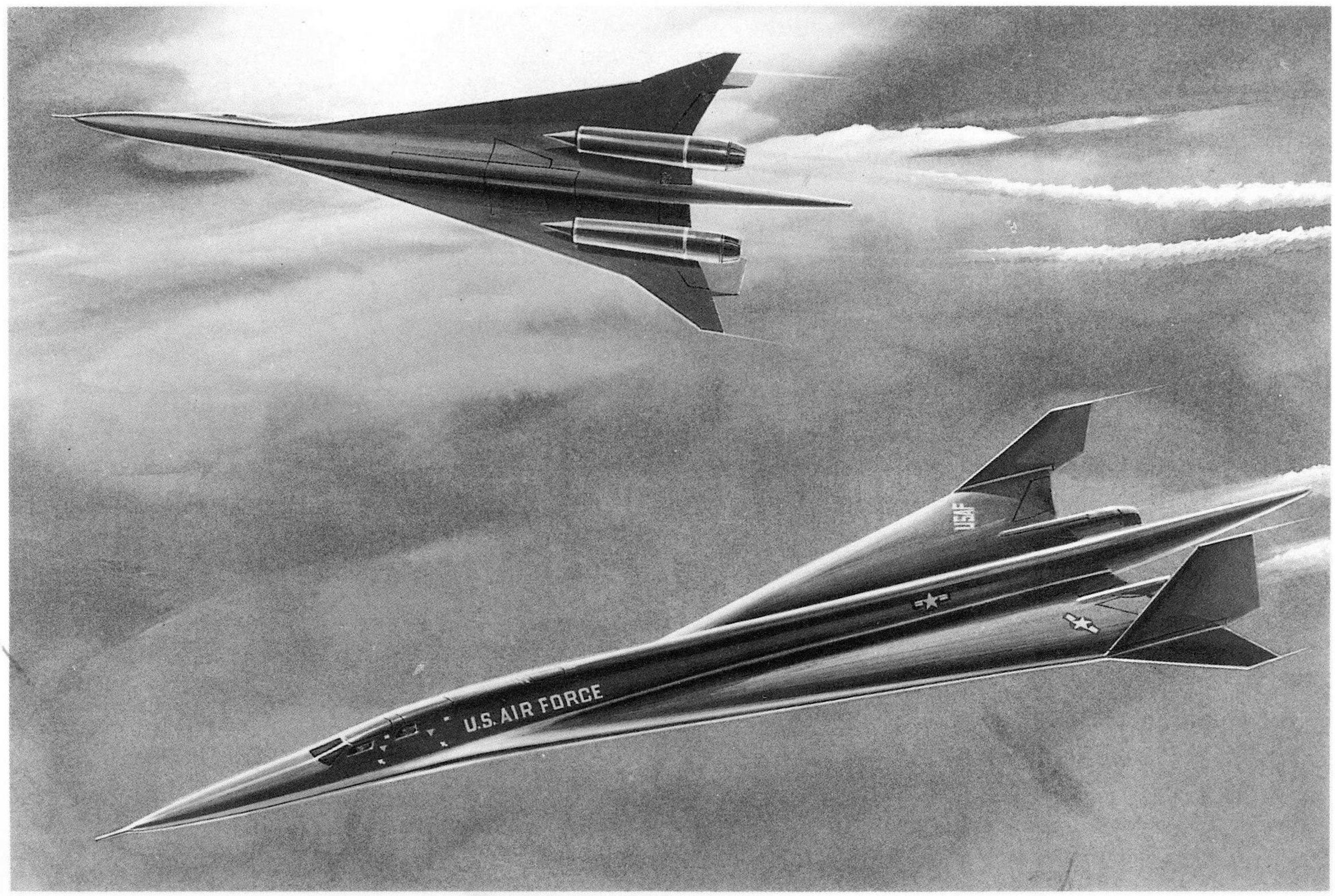
subsonic speed (the author does not believe the widely circulated reports that it cruises at Mach 2) and is seen by most defence systems from almost edge-on, because in most missions it probably flies at low level (this point will be returned to later). This explains its flattened appearance, because a low-level operator can afford to increase RCS and other "observables" in plan view in order to minimise these factors when seen from head-on or from the side.

Thus the overall shape is that of a tailless blended wing/fuselage aircraft in which the fuselage is so flattened, with sharp chines at the edges as in the SR-71, that it can almost be regarded as a low-aspect-ratio wing. In passing, one is strongly reminded of the Saab 35 Draken, and even more so of the Saab 210 research aircraft which preceded it. As the Saab 210 flew in December 1951 the Swedes can take a bow for having been the first to fly something at least shaped like a stealth aircraft, even if this was unintentional.

Artist's impressions of the CSIRS have indicated a conventional windscreen and canopy for the pilot (the only crew member). The author has no information on whether there has been a technical breakthrough which prevents sunlight from being reflected from Plexiglas, or whatever transparent material is used, but it would be a nice problem for a physicist to create a material acceptably transparent to light to give the pilot a perfect view of the world outside whilst at the same time never giving any telltale glint which could give away the presence and location of the aircraft to an enemy. Bearing in mind the extremely short wavelengths of visible light the answer almost certainly lies in photographically etching the outside surface of the transparent areas with an extremely fine geometric pattern of parallel lines or other irregularities which would cause incident light to be scattered through a 180° solid angle from each point. This could be just one of dozens of stealth techniques which have probably already been patented in the USA, and which could earn money from licensees all over the world by the year 2000.

Many of the patents are bound to concern the engine installation. According to the Italeri 1:72

Below: This was what Boeing Military Airplane Co came up with after USAF studies for a supercruise (supersonic cruise) fighter. It was planned with stealth in mind, but its IR signature and noise would be very obtrusive.



plastic kit of what that model company called the F-19—the top-selling kit of 1986—the centre fuselage, or centre wing, of the Lockheed has a top of roughly cylindrical form, straight in side view but arched upwards towards the centreline. Thus there is plenty of internal volume along the centreline, but the "fuselage" becomes shallower as one moves away to left or right until where it joins the wings proper the depth is only a few inches. As explained previously, a lot of the internal volume must be occupied by ducts for cold air drawn in to surround the jetpipes and both slow down (for noise reasons) and dilute (for IR reasons) the propulsive jets.

Italeri guessed that the extra air is taken in not through the main inlets but through giant louvres in the upper surface further aft. Here the wing (or rather, fuselage) is trying to lift the aircraft, and for best efficiency the pressure here ought to be below that of the surrounding atmosphere, especially if the wing has a "rooftop" or "supercritical" profile This is not to doubt the practicability of dorsal inlets, but they would be much better underneath. Probably the secondary air inlets are both above and below.

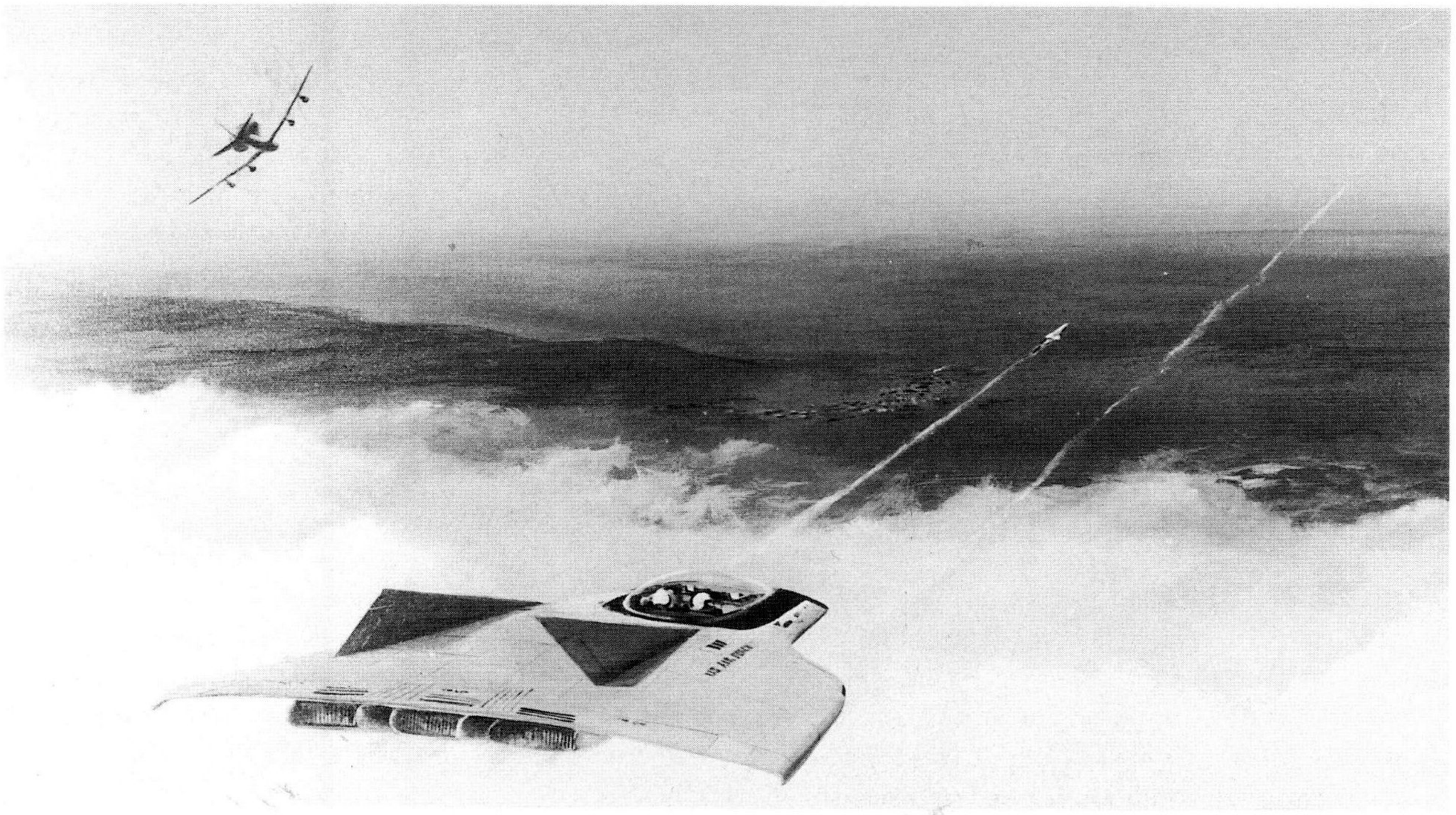
At the back there must be two large propulsive nozzles, possibly not circular but of a modified triangular shape, through which are ejected the cool and quiet propulsive jets. It is because of the basic character of these jets that the author doubts the reports of Mach 2 cruise. Highly supersonic aircraft must be propelled by highly supersonic jets, quite out of character with the demands of stealth.

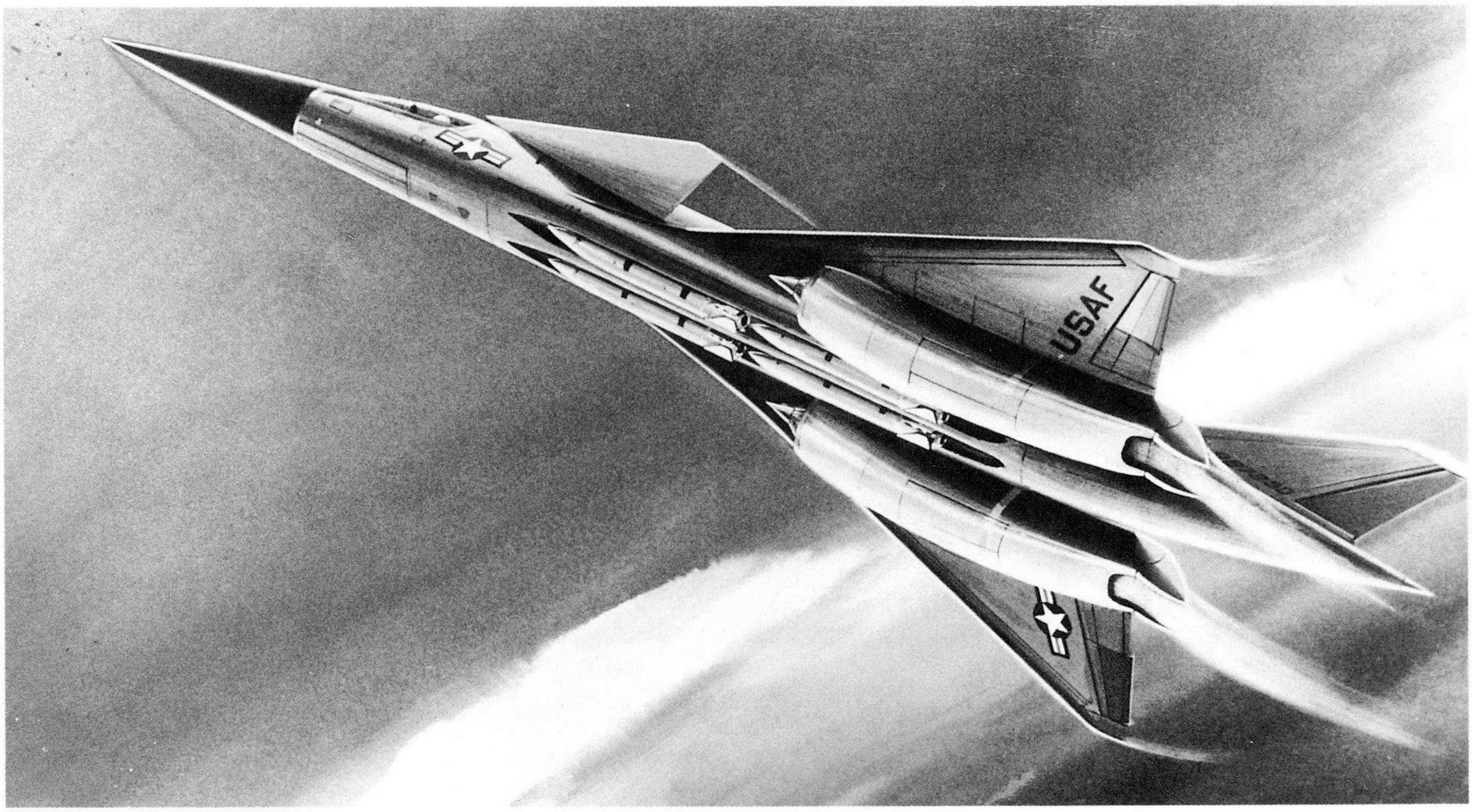
Vectoring jets?

What remains unknown is whether, as there is a lot of structure downstream of the F404 primary nozzles in order to deny enemy IR detectors any sight of sufficiently hot metal to provide a target for AAMs, any attempt has been made to use the shrouding surfaces to vector the propulsive jets. There seems, however, no doubt that the stealthy Lockheed is incapable of operating except from runways, and if this is the case then it almost destroys the value of the so-called "survivable" part of its CSIRS designation.

The Lockheed stealth aircraft can obviously carry a typical range of tactical reconnaissance sensors, such as forward and oblique optical cameras, IR linescan and, possibly, SLAR (sideways-looking airborne radar). A SLAR is by no means certain, however, in that it is an active (emitting) device whose signals could be detected as a great distance, while the other sensors are passive. Some modern

Below: A June 1987 drawing by a US DoD artist showing how a stealthy fighter could knock down a hostile AWACS (while the friendly AWACS banks away, somehow immune).





Above: This 1980 drawing by Boeing was not a stealth proposition, but it did feature conformal weapon carriage for lower supersonic drag. Stealth aircraft carry stores internally.

radars are quite stealthy, however, and there is no technical barrier to a discreet or low-observable SLAR. All these sensors are undoubtedly packaged on a pallet which fits into an internal bay under the aircraft's broad and extremely smooth belly. When needed for strike missions this pallet is presumably removed and replaced by a weapons pack. The latter has been said to include two AGM-65 Maverick missiles, which are the most widely used of the USAF's current precision ground-attack missiles.

AGM-65 exists in several forms, with guidance by a locked-on TV seeker, or by an IIR (imaging infrared) seeker or by homing on a laser-designated target. Use of a laser implies an emission which negates stealth design, but as it would occur highly directionally and only momentarily seconds before arrival of a 298lb (135kg) warhead this is probably not serious. Indeed in Tom Clancy's book *Red Storm Rising* so-called F-19s loiter around heavily defended targets surrounded by Warsaw Pact armies and designate each in turn for "smart" missiles delivered by ordinary F-111s and Tornados which simply zip past at Mach 1. This is not impossible, but it seems to be stretching the capabilities of stealth design a little too far.

The "IRS" for in-weather reconnaissance/strike shows that the Lockheed is intended to penetrate hostile territory in conditions of bad optical visibility, such as heavy rain, snow or fog, and either bring back multisensor imagery taken from quite close range or else deliver a precision attack. Such an aircraft clearly needs plenty in the way of all-weather and night navigation and flight-control systems. We know that Westinghouse provided the electric power and distribution system, and Lear Siegler the advanced FBW (fly by wire) flight control system. Of course, the new Lockheed is a digital aircraft, with all the computer power, MIL-1553B data bus systems and overall avionics architecture that one can today take for granted. One way in which it differs is in its wish never to emit any detectable radiation while over enemy territory.

It is believed that Lockheed delivered an initial batch of 20 aircraft, painted with black or grey ferrite-ball paint, followed by a front-line batch of 100. *Jane's* thinks the first 20 went to the 4450th Tactical Test Group at Nellis. Regular squadron aircraft are said to have operated from Alaska, the UK and Japan, and it was a design requirement that with outer wings folded the aircraft should fit into a C-5A. Maybe this is a surer way of getting them overseas than trying air refuelling with something invisible!

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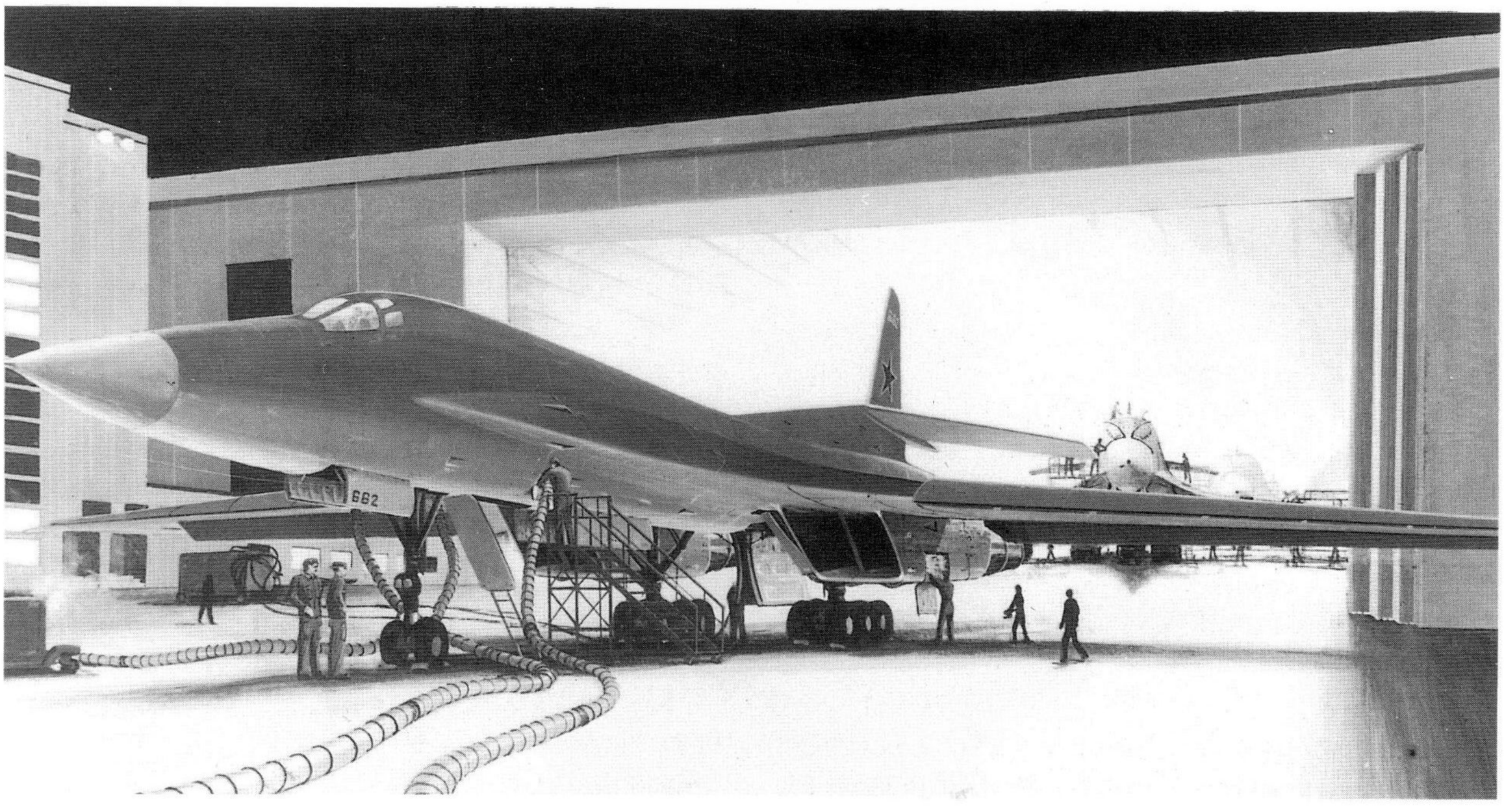
The Northrop Concept

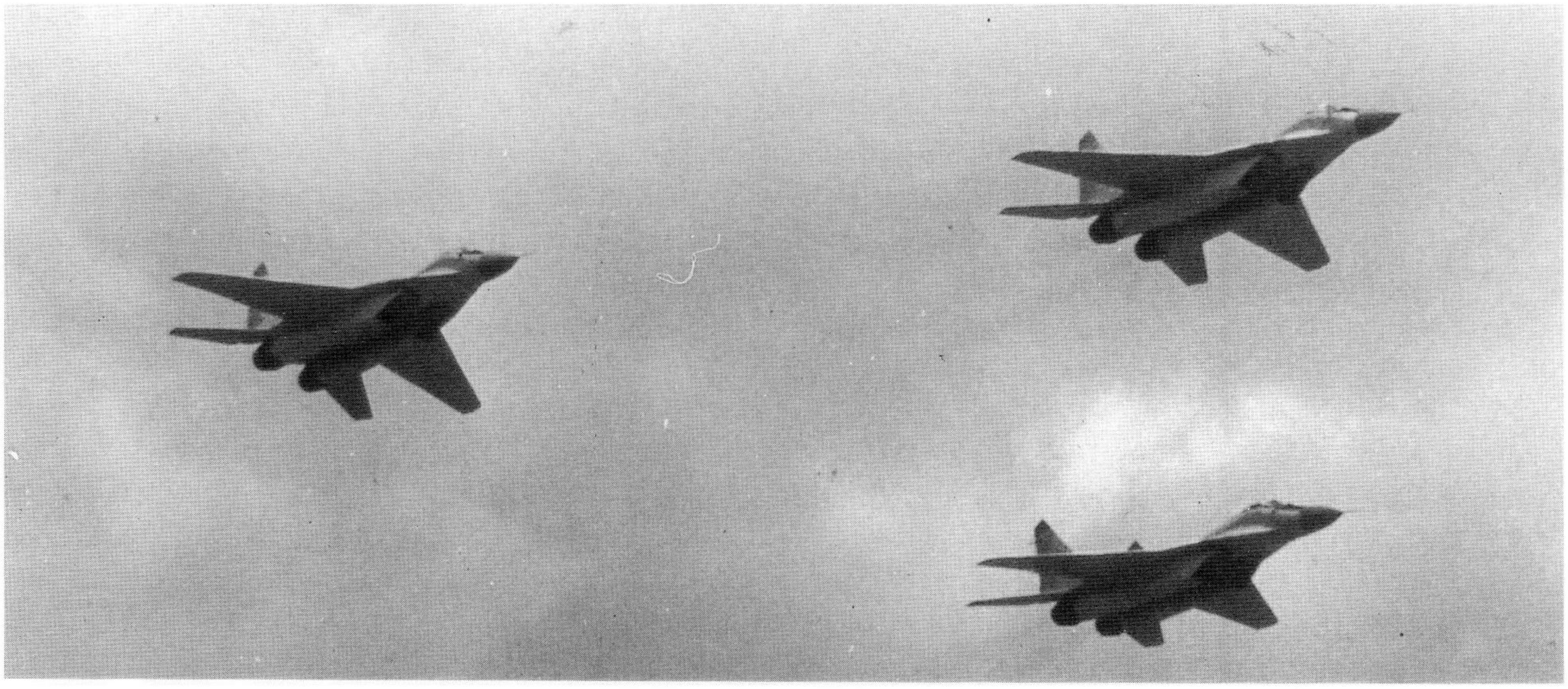
LOCKHEED SEEM unquestionably to have pioneered stealth technology, but so far their main commercial return has been to produce a relatively small aeroplane for tactical operations with the USAF. They might have preferred the much bigger prize of the world's first stealthy strategic bomber. This mighty task has been entrusted to Northrop.

The resurgence of the bomber has been one of the truly remarkable about-faces of military planning. Back in April 1957 the British Government and Air Staff went so far as to agree that *all* combat aircraft were obsolete, and that future air forces would use nothing but missiles. In the 1960s and 1970s, almost all nations were agreed that there was no future for the large strategic bomber, as most of the roles of such aircraft had already been taken over by the ICBM and SLBM. Russian development of large bombers for the Long-Range Aviation was cancelled, and many already in service were transferred to the naval AV-MF and reassigned to a maritime role. In the USA the B-70 was cancelled in 1964, plans to develop the Lockheed A-12 into a reconnaissance bomber were likewise abandoned, and the next-generation B-1 was cancelled in June 1977. But today we have nearly 500 "Backfires", the world's biggest aircraft factory already in production with the enormous "Blackjack", 100 B-1Bs in service with SAC, and a complete new assembly hall at Palmdale beginning to fill up with a production line of ATBs (Advanced Technology Bombers)!

One of the reasons given by President Carter for cancelling the B-1 in 1977 was that the cruise missile would enable the lumbering old B-52 to penetrate hostile airspace throughout the foreseeable future. Even carrying SRAMs (AGM-69A short-range attack missiles) to suppress the defences, this was obviously

Below: The Soviet Blackjack is generally regarded as a much bigger counterpart to the B-1B, but Western analysts doubt that it incorporates such advanced stealth features.



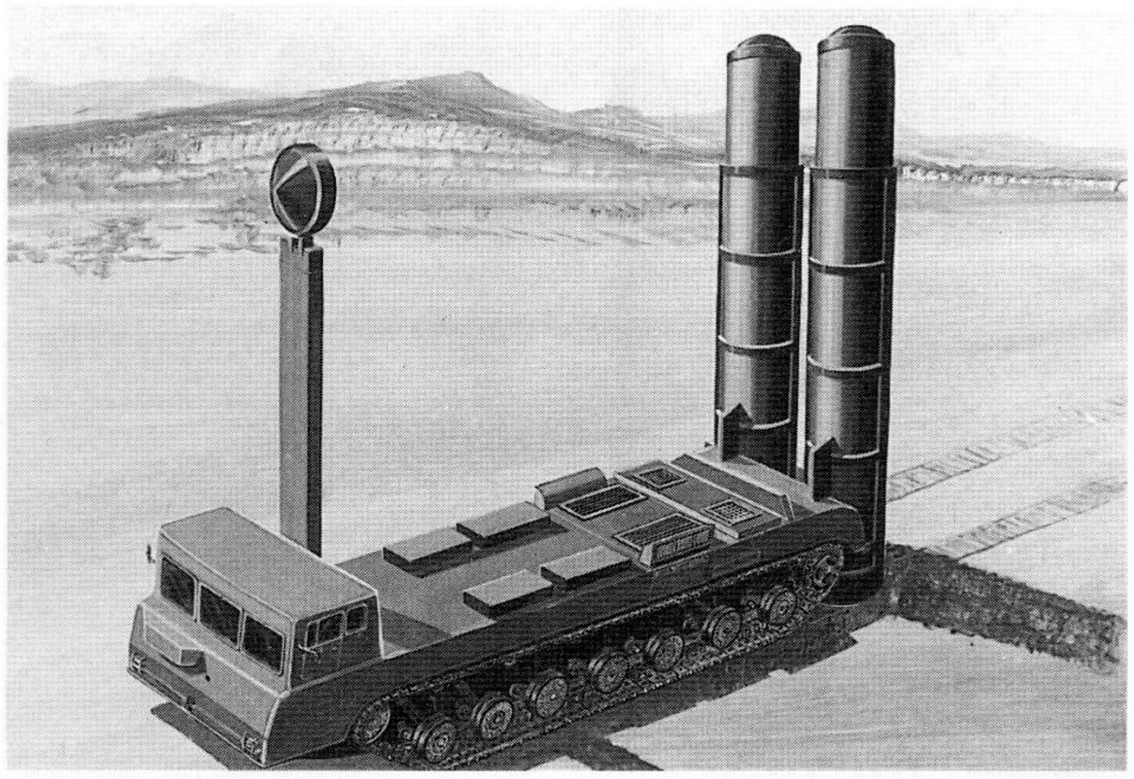


Above: No Western bomber or reconnaissance aircraft would like to come up against this formation of MiG-29 Fulcrums, with their look-down shoot-down radar, IR and missiles.

a hope that was not going to be realised. Accordingly, President Reagan ordered production of 100 B-1Bs, each with far greater capabilities in both nuclear and conventional warfare, and with defensive systems of a totally new order. These menacing dark-camouflaged swing-wing aircraft, despite a few teething troubles, have utterly transformed SAC and are certain to have a front-line life extending well into the next century. But in 1980 far-ranging studies threw up the predictable answer that, because of continued Soviet deployment of better radars, better SAM systems and better interceptors, even the B-1B would begin to find life too perilous after the early 1990s.

Beyond the B-1B

There was still no absolute certainty that a new strategic bomber beyond the B-1B would be needed. All fixed targets, such as airfields, can be knocked out far more effectively by long-range missiles. The B-1B itself was originally judged worth having on account of its versatility and flexibility in both nuclear and conventional warfare, against fixed and mobile targets on both land and sea, and on its good communications and recall capability which is something at present impossible with all ICBMs and SLBMs deployed so far. Moreover, it was reasonable to predict continued improvement of the range,



Above: The Soviet SA-X-12B can intercept all aircraft out to 100km (62 miles), as well as tactical ballistic missiles, cruise missiles and some types of strategic ballistic missile.

accuracy and lethality with which the B-1B could knock out defences with SRAMs and heavily defended targets with cruise missiles. Nevertheless, despite these factors, such Soviet air-defence equipment as the fantastic new radars (for space defence as well), the SA-10 and SA-12A Gladiator and SA-12B Giant, and the MiG-29 "Fulcrum", MiG-31 "Foxhound" and Su-27 "Flanker" made it clear that all of the vast Soviet airspace was rapidly becoming perilous.

Moreover, the B-1B was very far from being the optimised stealth bomber. The B-1A was designed to fly at high altitude at Mach 2, and it was modified into the B-1B to fly at Mach 0.92 at 500ft (152m). The result is thus very much a compromise, and though it is a deeply impressive and undeniably

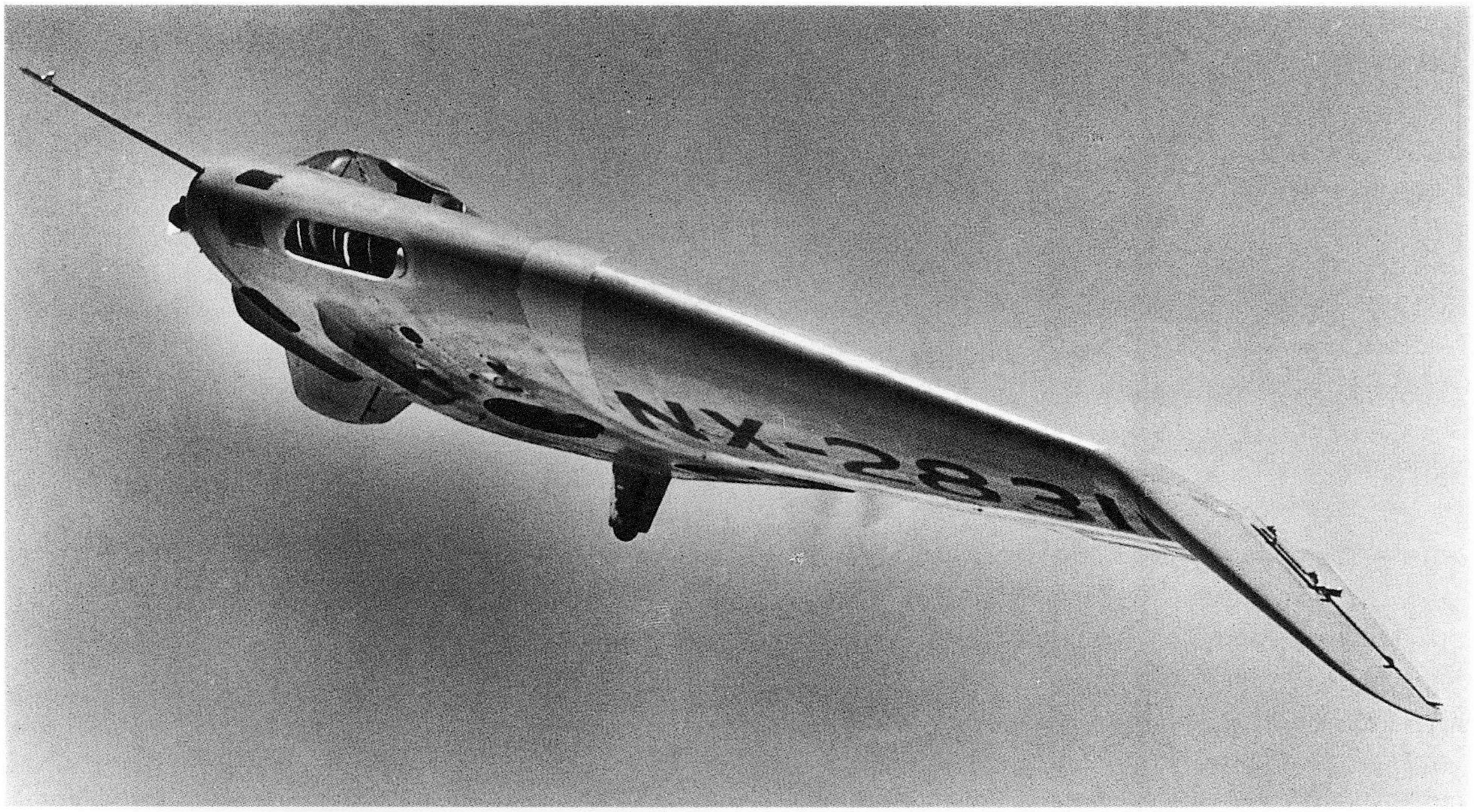
formidable aircraft, the B-1B will age more rapidly than an uncompromised stealth low-level design. Accordingly the strategic plan of SAC was that procurement of the B-1B should be terminated at No 100 and that, subject to successful development, an even greater sum should be budgeted for the procurement of a slightly greater number of ATBs. A further important reason for wanting a bomber is that the latest Soviet strategic missiles, such as SS-24 and SS-25, are mobile and immune to attack by missiles of their own kind.

It appears that there was no industry competition. Instead, in October 1981 the Department of Defense announced that an initial $7,300 millon had been awarded to Northrop Corporation as prime contractor for the first phases of the ATB programme. Northrop would be assisted by BMAC (Boeing Military Airspace Company) of Wichita, LTV (Vought) of Dallas and GE (General Electric) of Evendale, Ohio. It would be reasonable to assume that BMAC will use its great "paper project" experience with advanced bombers and will also manage the on-board avionics systems integration (it was responsible for the offensive avionics system of the B-1B). Vought is famed for manufacture of major portions of airframe structure, which would be sent to Palmdale initially by air and, in production, probably by rail. GE is supplier of the engines, which are widely said to comprise four F101 turbofans broadly similar to those of the B-1B but, surely, without augmentation (afterburning).

ATB work began with a fairly quick study of configurations, and the design and flight test of a piloted model to about one-third linear scale. This might, for example, have been powered by four Garrett TFE731 turbofans, which would be of about

Below: The Soviet SS-25 ICBM has been made mobile in the realisation that anything that is fixed – such as an ICBM silo or, to a much greater extent, an airfield – has no chance of surviving in the event of war.





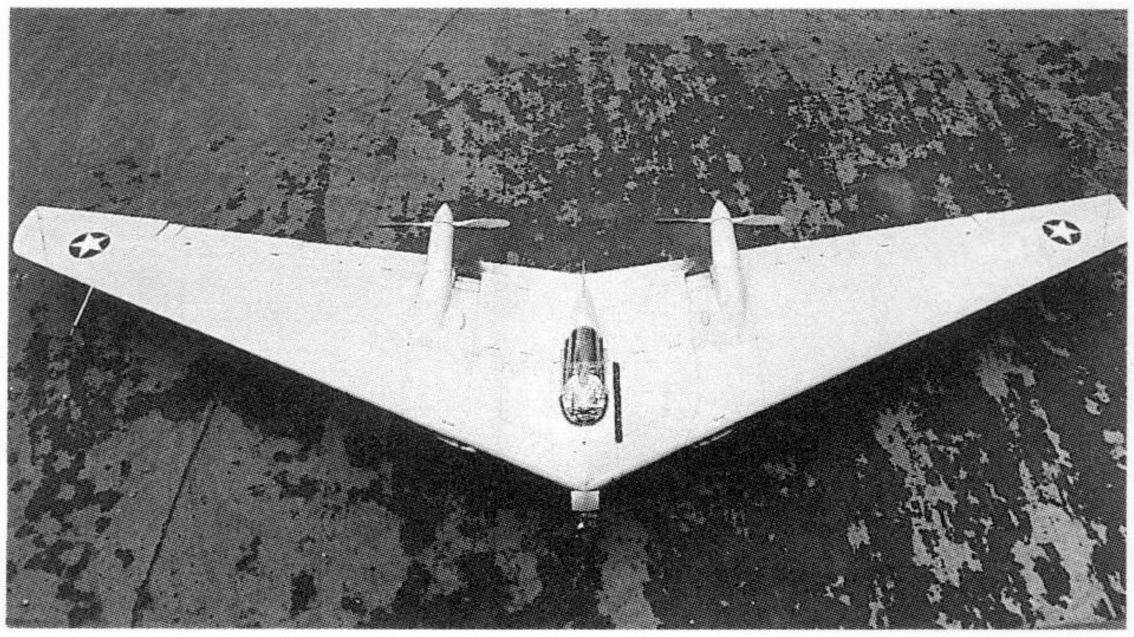
Above: The N-1M, an early example of Northrop's brilliant flying wing aircraft, was first flown in 1940. All the aircraft of this family would have had marvellous stealth characteristics, but nobody considered this at the time.

the right size. According to *Jane's* "A scaled proof-of-concept vehicle is believed to have been flying since 1982". Bearing in mind the enormity of the ATB task the timescale was very tight indeed, and simple arithmetic shows that not very much time was spent in reducing the risk, getting the configuration finalised and demonstrating the new technologies. According to author Bill Sweetman, writing in *IDR*, this phase was completed in early 1985, though detail engineering design of the ATB must have begun well before the latter date. Certainly the $7,300 million award was intended to include the construction of at least one static/fatigue test specimen and at least one flight article. The latter was expected to fly in late 1987 but now is certainly not going to fly before the first quarter of 1988. Sweetman says "substantial cost overruns . . . knocked 20 per cent off Northrop's research and development profits".

Flying-wing bombers

From the very beginning the ATB has been described, often semi-officially, as a "flying wing" aircraft. Northrop was the world's greatest pioneer of flying-wing aircraft, starting with a 90hp two-seater of 1928 and progressing via a host of increasingly fascinating propeller and jet designs up to the monster XB-35 (four R-4360 Wasp Majors) and YB-49 (eight J35s) of 1943–49. The YB-49 strategic bomber had a span of 172ft (52.43m) and could not only fly at 520mph (837km/h) but carry a 30,000lb (13,608kg) bombload for over 4,000 miles (6,440km). It was a true flying wing, its vast outline broken only by a cockpit blister, a small tailcone just behind the trailing edge and four wing fences which grew into small fins above and below the trailing edge. For its time these monster all-wing strategic bombers were an incredible achievement, but—despite Watson Watt's suggestion of a decade earlier—nobody then paid much attention to stealth capability.

Of course, if the ATB flies before this book appears, all may be revealed, and so will incorrect guesses. At present all that can be said is that the ATB is expected to be powered by four F101 engines, probably each rated at about 22,000lb (10,000kg) thrust, no afterburner being fitted, sufficient to confer a low-level maximum speed of about Mach 0.85, or 647mph (1040km/h). Northrop's patented flight-control system with split-surface "deceleron" ailerons at the wingtips worked adequately in the earlier flying wings, but a different



Above: First flown in December 1942, the Northrop N-9M was built as a scale model of the giant XB-35 heavy bomber. It was a delight to fly, despite the fact that it had no fins or control surfaces other than "deceleron" ailerons.

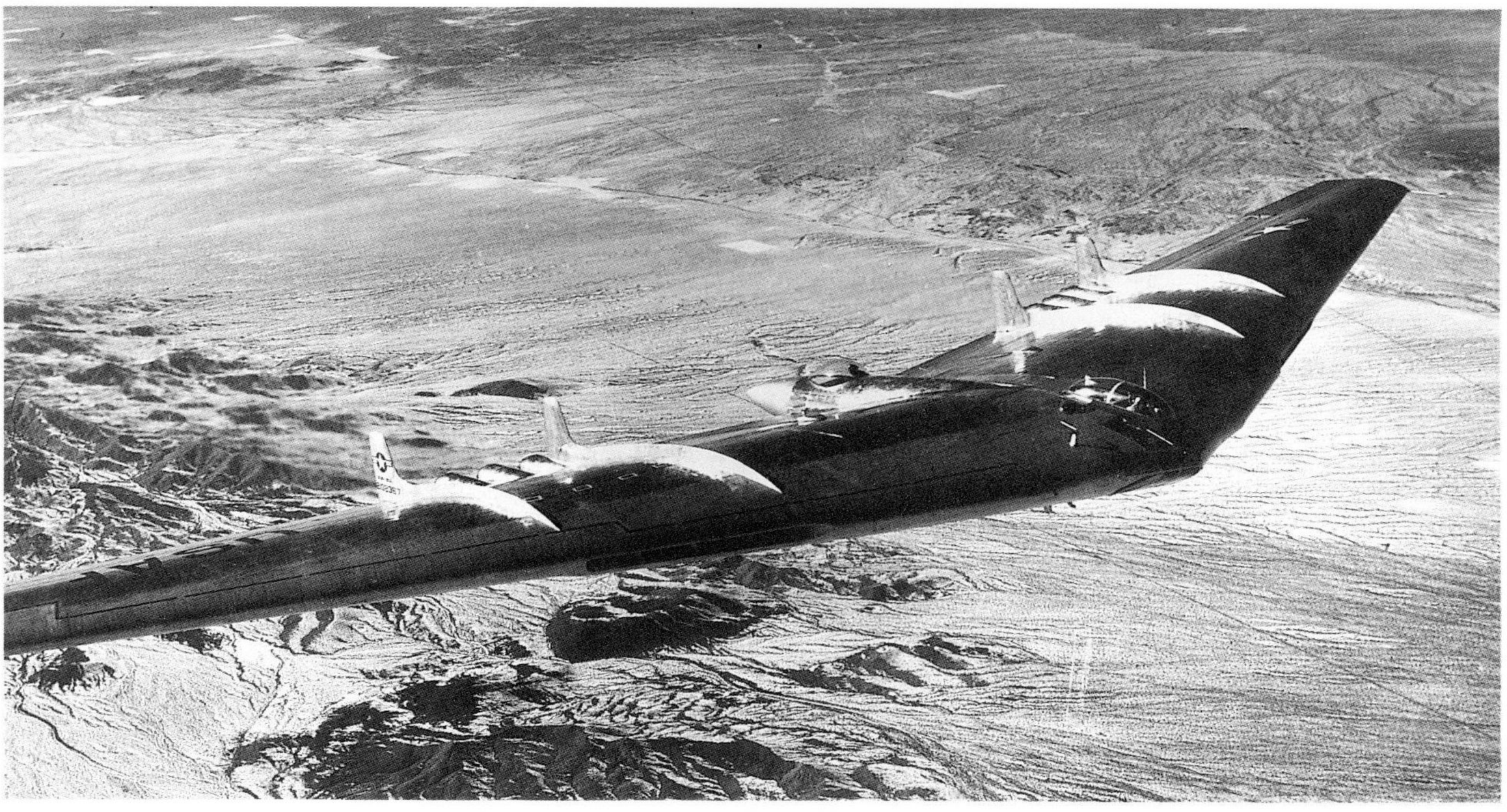
system may be used in the ATB (certainly of digital fly-by-wire type). The outer wings are certain to be of fairly high aspect ratio to give good cruising efficiency for long range. Crew, most of the fuel, bombs and engines are grouped in a greatly thickened region in the centre, and this is likely to be bigger than in most of the unofficial artist's impressions.

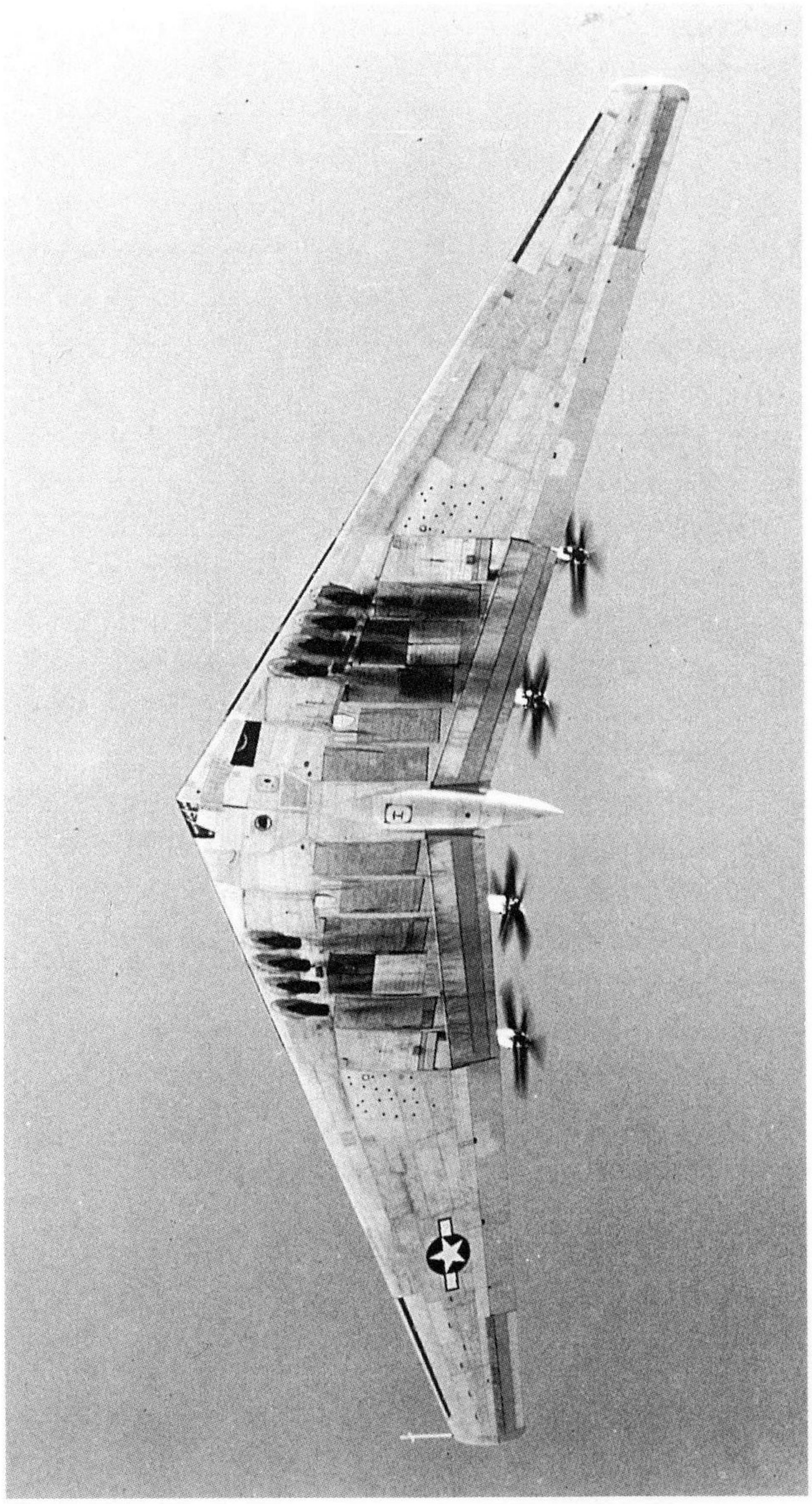
The engines are paired on each side, with inlets above the wing so arranged that the air ducts curve down in a flattened S-shape to the engines aft of the trailing edge, terminating in flat rectangular nozzles from which the cool and relatively slow propulsive jets emerge. No radar signal entering the inlets can "see" anything but the upper or side wall of the duct, which is skinned in noise- and radar-absorbent sandwich material. It would be logical for the nozzles to incorporate thrust-vectoring flight-control surfaces.

According to Joseph Jones, writing in *Air International*, the ATB has an underlying structure mainly of titanium, with epoxy-graphite composite skins. Sweetman writes of "radar-absorbent honeycomb structure, using specially treated cores which are manufactured by . . . Hexcel in a new facility at Tempe, Arizona". Jones again: "The detection signatures . . . are said to be of the order of one-millionth of a square metre, giving a response on a radar screen similar to that presented by a humming bird in flight . . . The materials . . . are worked into loose molecular structures to provide irregular, porous, energy-baffling honeycombs. Like the sound-deadening structures in anechoic chambers, these materials 'capture' radar, IR or laser signals and bounce them around inside their cellular structure like a table-tennis ball until they are absorbed".

Of course, the ATB will use a combination of self-contained inertial, terrain comparison and Navstar Global Positioning System navigation aids, so that its track is always accurate to within a few metres. It

Below: Powered by eight J35 turbojets, the Northrop YB-49 was a truly remarkable strategic bomber, and it would be interesting to try to discover its RCS. It is seen here on a transcontinental flight in February 1949.





Above: Looking up at one of the Northrop XB-35 piston-engined bombers which preceded the jet versions. This example has contraprops, whose side area made it possible to eliminate fins, such as were later added to the YB-49 opposite.

may carry SRAM II missiles to take out particularly dangerous defence sites, but its chief weapon is likely to be the AGM-129A advanced cruise missile. If it drops bombs, these may, writes Jones, contain new non-nuclear explosives such as spin-polarized hydrogen (SPH) and metastable hydrogen (MSH) which both offer "one hundred times the energy release of nitroglycerine".

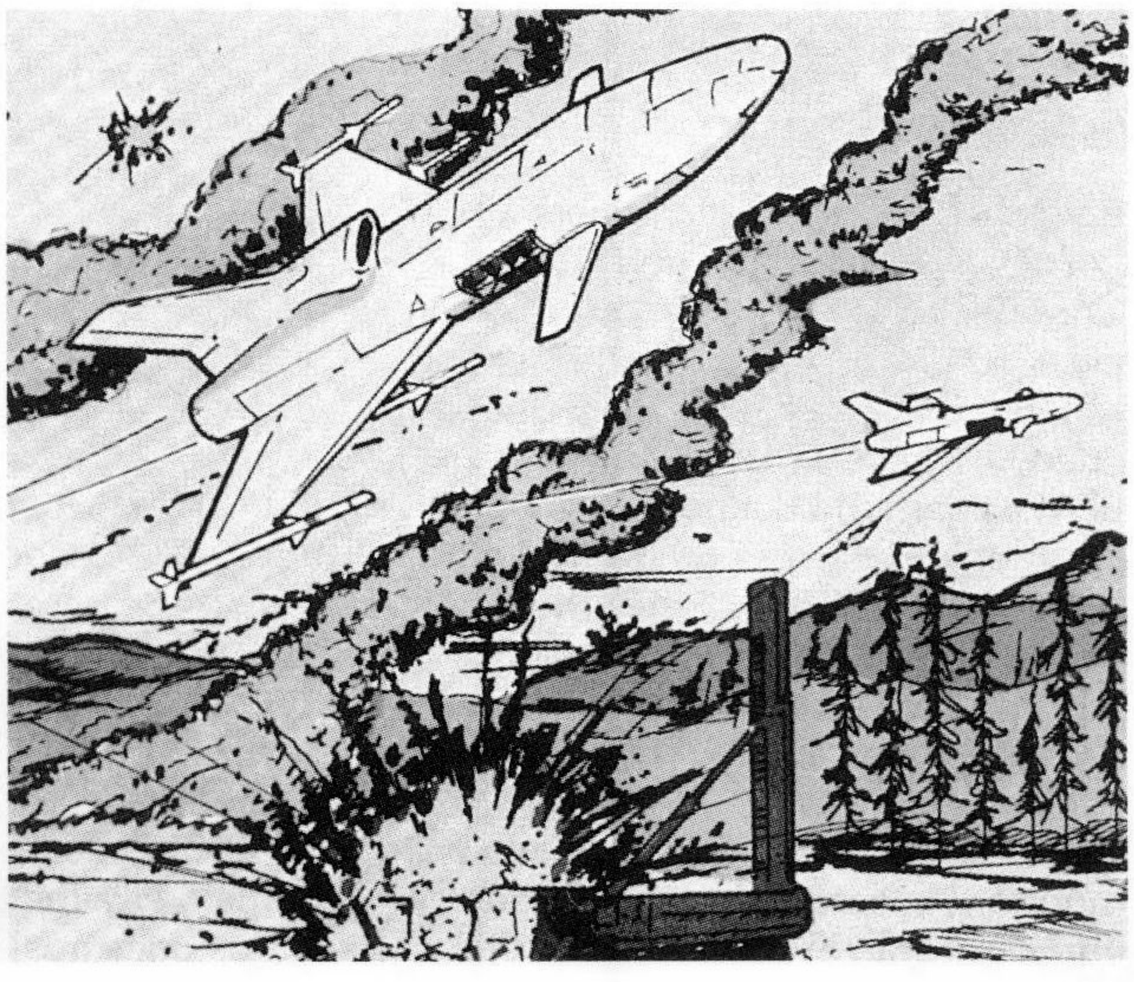
Obviously, all weapons will be carried internally, probably mounted individually on rapid-action rotary doors which in a single 360° rotation release the selected weapon and then restore the original perfectly smooth belly profile in a fraction of a second. Span of the ATB is expected to be not very different from that of the YB-49, but it will probably be roughly twice as heavy, in the 400,000lb (181,440kg) class. A common guess at the weapon load is one-tenth of this value, carried for a range of 5,000nm (5,758 miles, 9266km). It will undoubtedly have provision for flying boom aerial refuelling.

USAF designation

Another guess which seems logical is that the USAF designation for the ATB is, or will be, Northrop B-2. According to General Thomas H. McMullen, at the time (1986) Commander of ASD, the USAF Systems Command's Aeronautical Systems Division, the new bomber will be "a fundamental weapon . . . for relocatable targets . . . In certain conventional-warfare roles it will have a formidable capability that could not be matched by any other system . . . It will carry an array of sensors to detect electromagnetic emissions, a high-resolution radar and infra-red sensors . . . coupled with a lot of training for the crew".

According to Sweetman, "Its Stealth features will presumably allow it to operate at high altitude above the Soviet Union, so that it can search effectively for ground targets". Certainly in the low level mission

Below: Published by Lockheed, this 1987 artist's impression shows stealth-technology cruise missiles. No illustration has yet been published of the AGM-129A Advanced Cruise Missile being developed by a team led by General Dynamics.



there is little chance of success in finding elusive targets, except perhaps by following railway tracks looking for SS-24 trains. If the ATB can indeed remain undetected at high altitude this will be an amazing achievement, and betoken a quantum-leap in the technology since the smaller Lockheed recon/strike aircraft was designed.

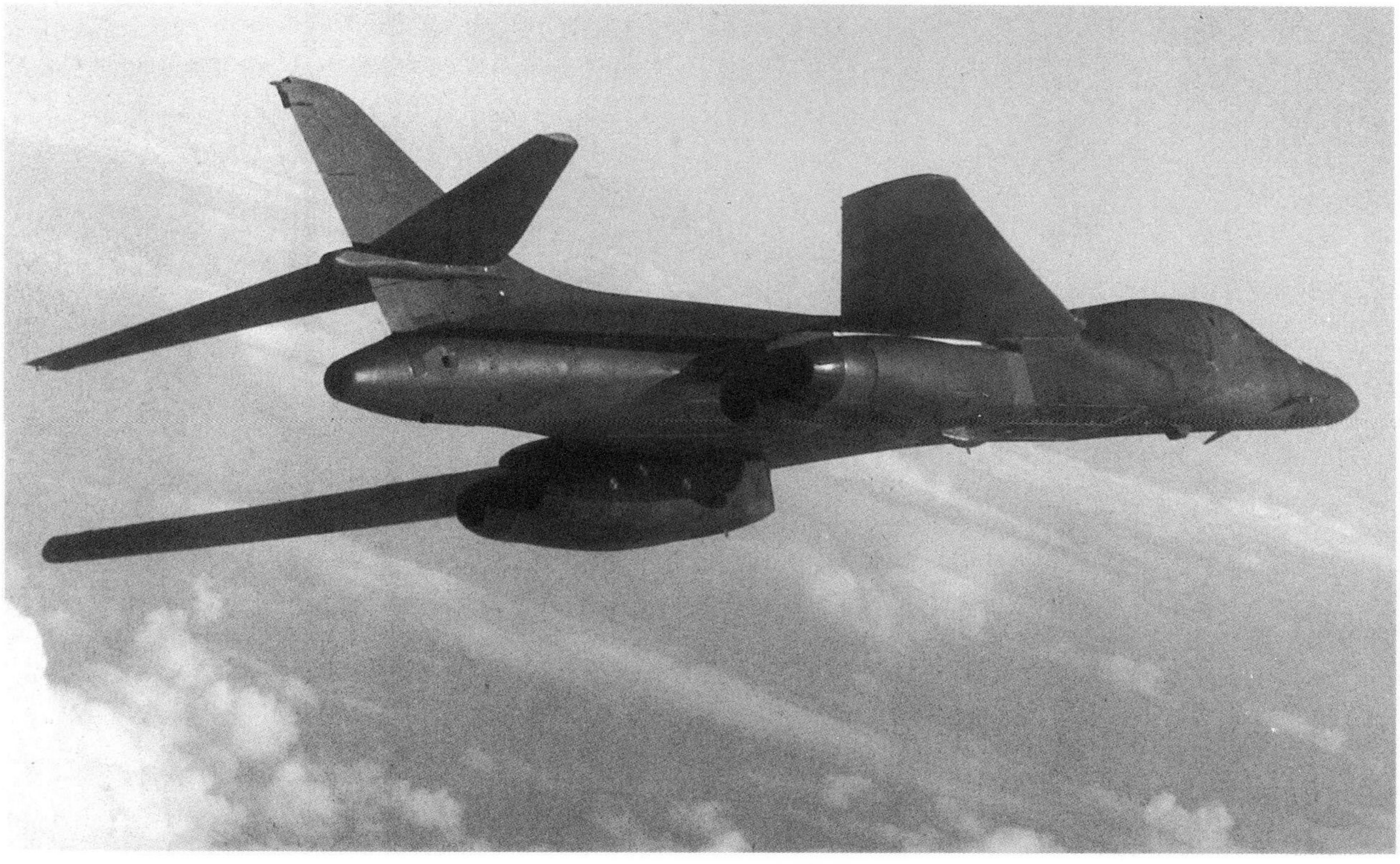
No more B-1Bs

Rockwell offered to continue the run of B-1B bombers with a further 48 priced at $195 million each, compared with an average $238 million for the original 100. The USAF initially hedged its bets, but good progress with the ATB led to rejection of Rockwell's offer. Instead the USAF intends to go ahead with the full planned production run of 132 Northrop B-2s, originally priced at $36,600 million (a figure almost certain to be exceeded).

Northrop's Advanced Systems Division at Pico Rivera, California, is said by *Jane's* to have completed a full-scale engineering mockup of the ATB by early 1986. By this time the big new assembly plant built specially for the ATB programme was fast taking shape on the side of Palmdale's vast airbase remote from all the more familiar (Lockheed and Rockwell) factories. The first flight is expected to take place direct from this assembly facility. It could even take place at night, and might end in Groom Lake or some other isolated facility.

The first base designated for the new Northrop bomber is Whiteman AFB, Missouri, which is also HQ of a Minuteman ICBM wing. A big reconstruction project is due here between 1989 and 1991. Moreover, SAC has stated that in Fiscal Year 1990, which ends on 30 June 1991, it will hand over to Tactical Air Command (TAC) one wing of FB-111A bombers which are currently assigned (unlike the B-52s) to the penetration mission. Sweetman has not unreasonably put two and two together and concluded that their replacement will be the first wing of B-2s at Whiteman. The remaining FB-111A wing is scheduled to be handed over to TAC in FY92, which ends on 30 June 1993. This is thought to coincide with the arrival of the second wing of stealth bombers. Deliveries of these remarkable aircraft are expected to continue until at least 1996, and there is a fair chance that, in contrast to what happened with the B-1B, a repeat order may be placed.

Below: By the time this book appears the Strategic Air Command will have almost all its 100 B-1B bombers. Though only partial-stealth aircraft, they have comprehensive ECM.



7

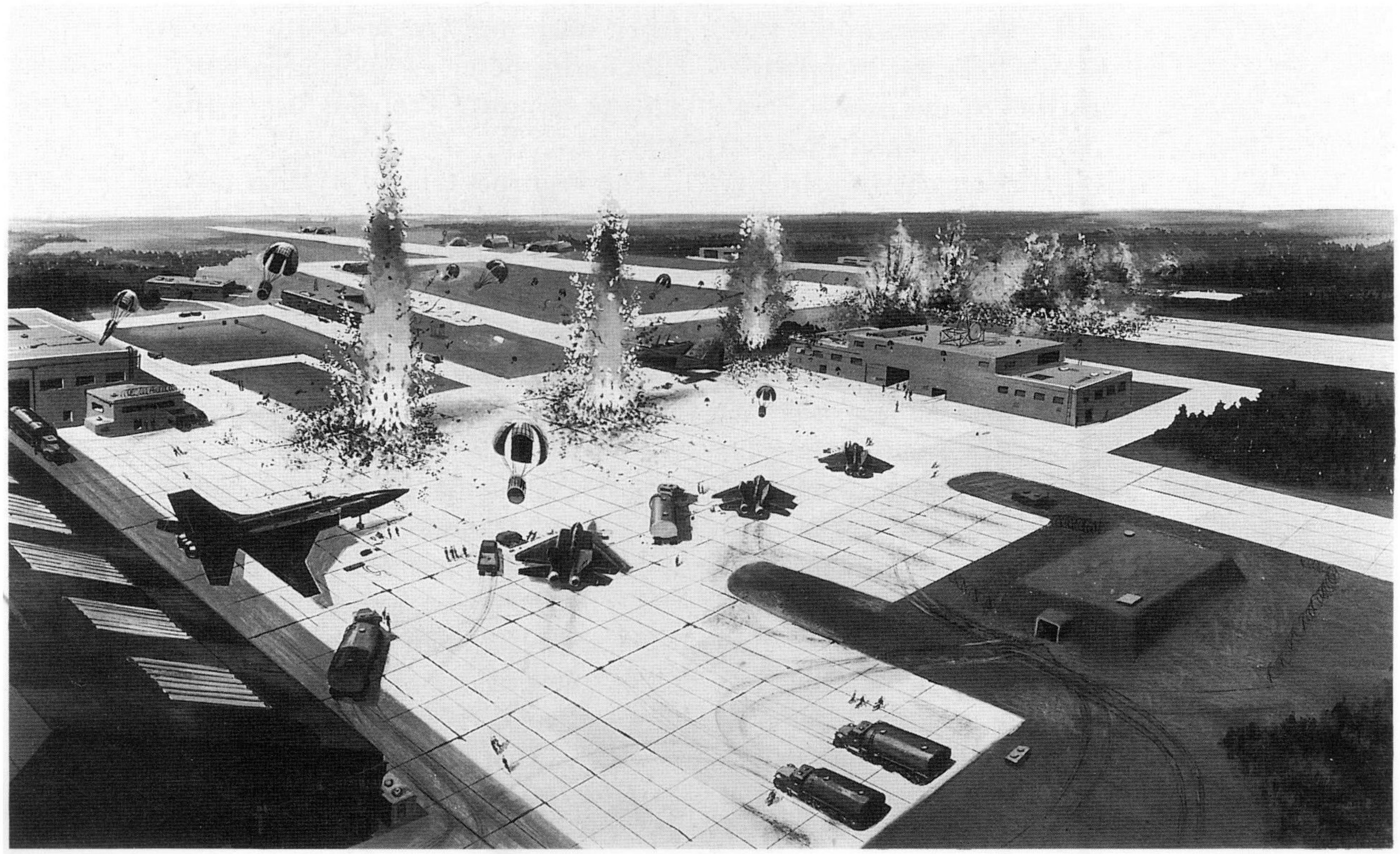
The 21st Century

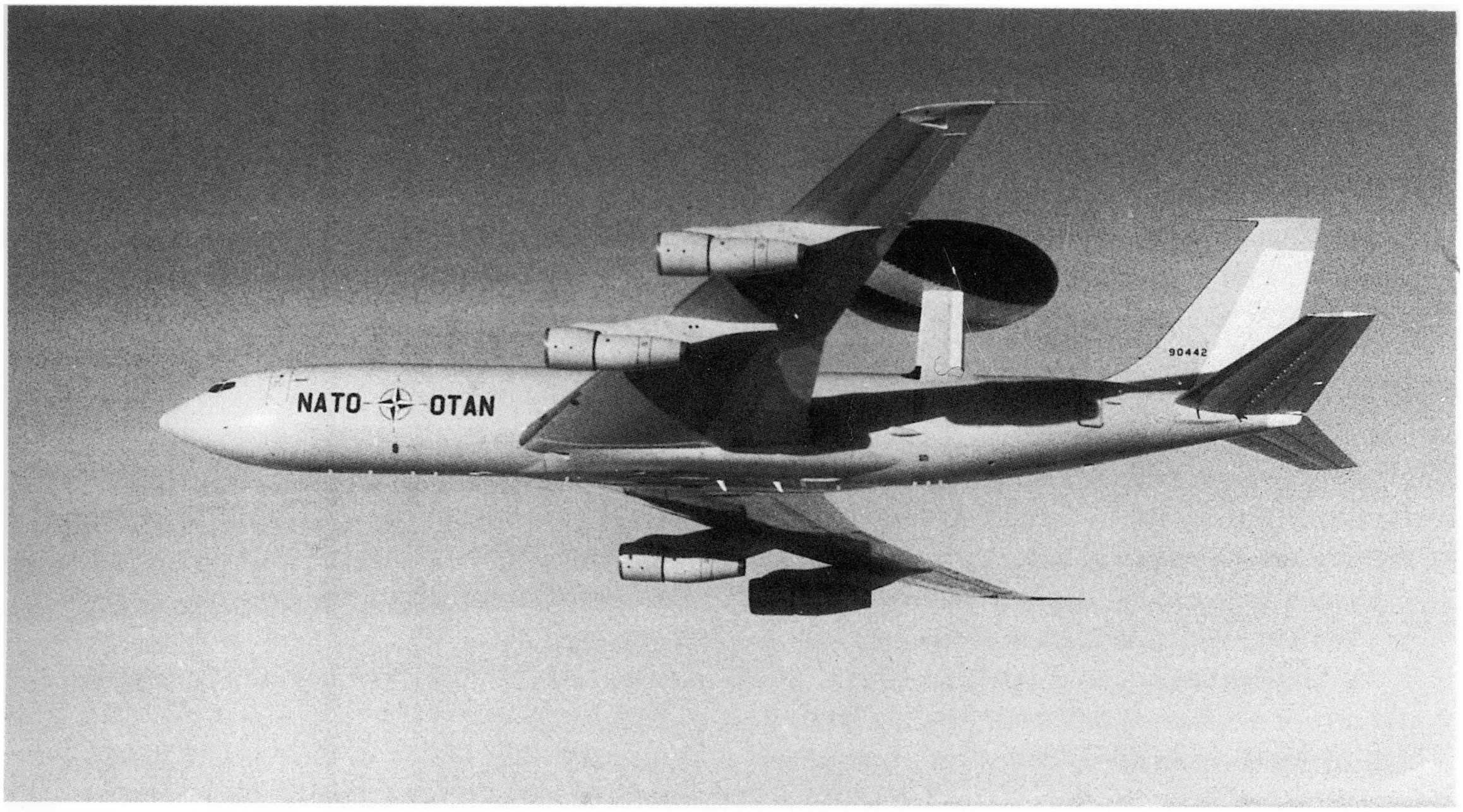
ONE OF THE FEW things concerning modern weapons that can be predicted with assurance is that they will get ever more expensive, and so will be bought in ever diminishing quantities. Major "technical breakthroughs" tend to accentuate this trend, and a rough guess of the author's is that stealth aircraft will come out about twice as expensive as the Brand X variety that everyone can see, hear and detect with radar and IR.

One probable outcome is that established stealth manufacturers will have a considerable inside edge in bidding for future programmes. Another is that established stealth aircraft, if they have proved effective, will be further developed and used for additional missions. For example it is not beyond the bounds of possibility that the Lockheed recon/strike aircraft could be developed with different sensors and weapons and find itself in the air-combat fighter role. As for the ATB, this could become the world's first AWACS (airborne warning and control system) type aircraft with any chance of surviving until Day 2 of a future war.

As for the crucial subject of survival, it clearly makes little sense to spend vast sums on fragile aircraft and then park them on the only spots on this planet which are certain to be absolutely obliterated by missiles within minutes of the start of any major war. If a giant airbase is destroyed by a nuclear fireball, by chemical attack or by various other nasty procedures, as would naturally follow—or, more probably, precede—any declaration of war by the

Below: This is how Hunting see their JP.233 dispenser being used; but why should anyone use aircraft to attack airfields when the job can be done totally by various kinds of missile?





Above: The author cannot understand how any warplane can survive on the ground, nor an AWACS in the sky. These flying lighthouses seem utterly vulnerable; and how could they control invisible stealth aircraft?

Soviet Union the resulting holocaust would obviously engulf any stealth aircraft that happened to be based there. This would seem to make their expensively won special property of being undetectable of only questionable value, unless they could be located somewhere else out of harm's way and unknown to the enemy. Whether there are any such airbases in the Western world unknown to the Soviet Union is problematical, but to the author there seems no justification in building aircraft that can survive in the air if they have no chance whatsoever of surviving on the ground.

An uphill struggle?

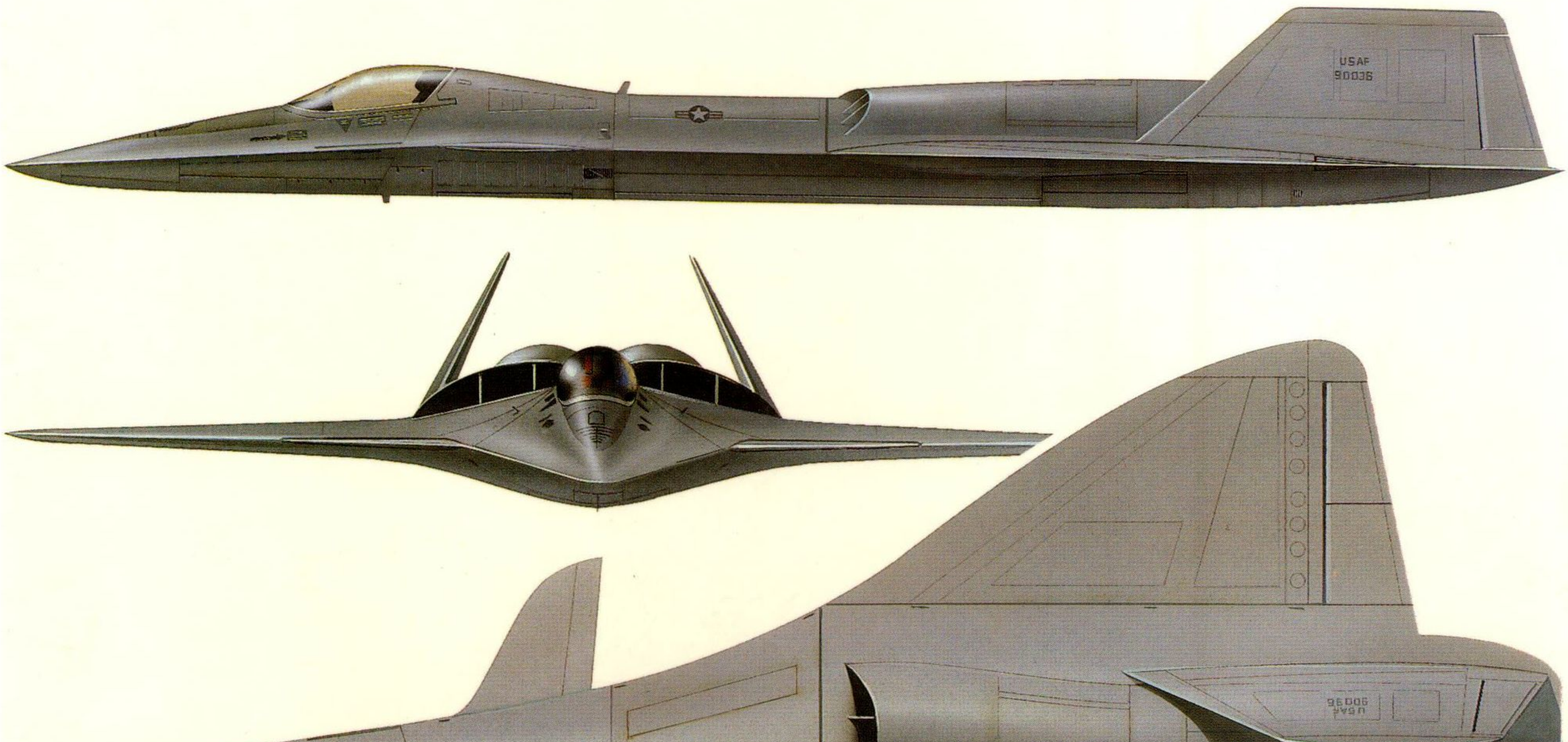
Today the stealth story is still at a very early stage, notwithstanding the way we were all told to get on with it in 1936. Aircraft built to be silent and invisible are still rare, exotic and regarded with considerable excitement. Design teams in Europe are solemnly planning programmes to build fighters that will not enter service until 1995 and yet which will blast out thunderous afterburner flames which advertise their presence from miles away, without the defenders needing any sensors at all! The author does not wish to lose friends, but he feels like asking "When will the penny drop? When will the people in positions of authority and responsibility come to realise that future warplanes must not be based on known airfields and must be of totally stealth design?" All other warplanes are obviously going to have no future whatsoever, except in peacetime, and it seems strange to create weapons that are for peacetime only.

This insistence on *all* warplanes shows that stealth is good for all missions that go anywhere near the enemy. Naval fighters and attack aircraft, anti-submarine aircraft, maritime patrol aircraft, big airlift transports and battlefield helicopters—especially battlefield helicopters!—all must be of 100 per cent stealth design. A few pilots may be just itching to win the VC or Medal of Honor, but the majority would probably agree that it is better to survive and fly a second combat mission. Just how you design a stealth AWACS aircraft seems to be more difficult than in the other cases, because such aircraft tend to be large, powerful, high-flying and to fill the sky with radar waves of titanic power. At present they think they can survive by using ECM, but this is clearly nonsense. If it were true, the B-1B would reign supreme and there would be no need to fork out $36,600 million for the ATB.

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