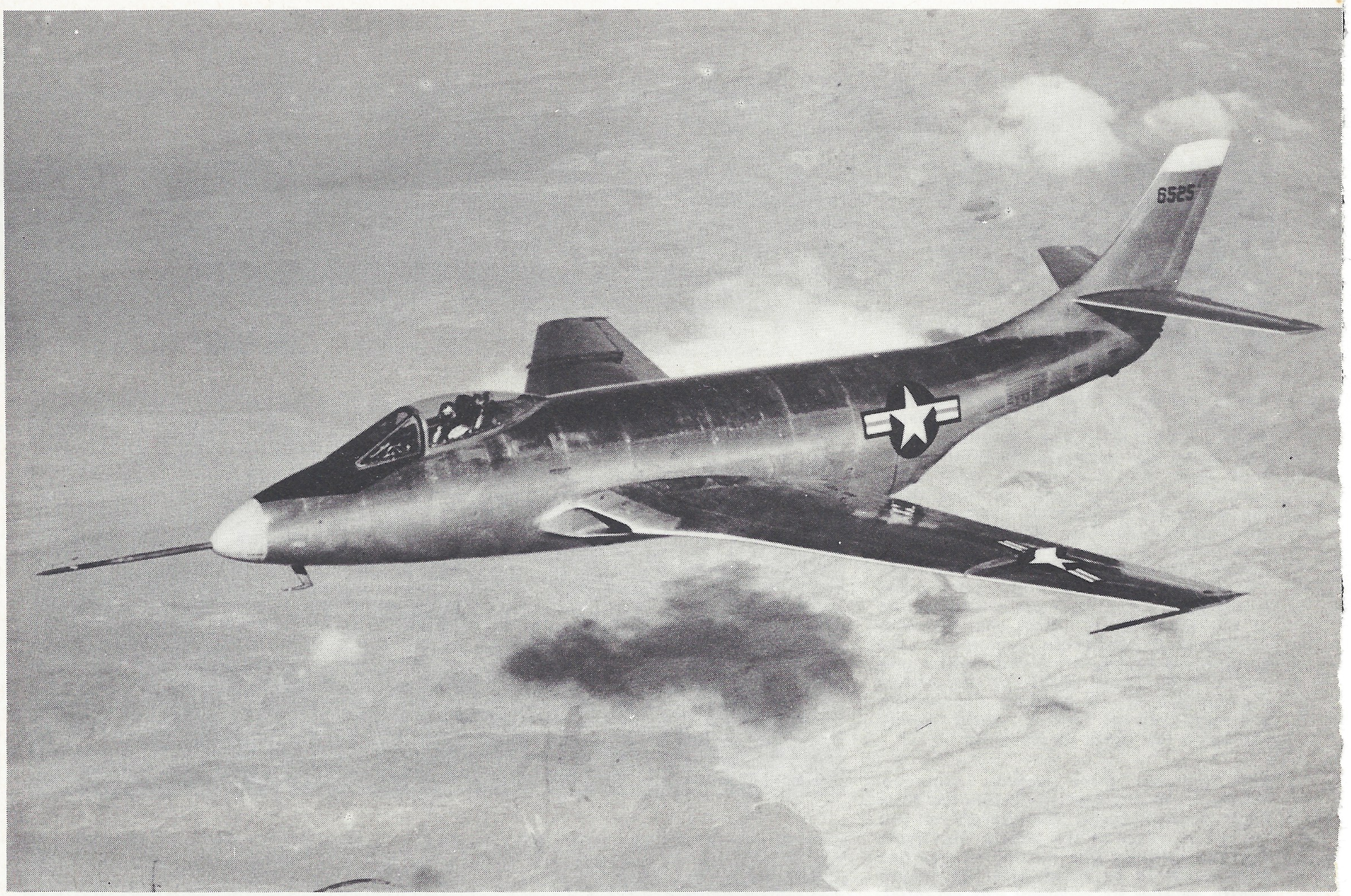


THE EXPERIMENTAL VOODOOS

The McDonnell F-101 Voodoo entered service with the USAF in 1957, yet the basic design, the XF-88, was first flown nine years earlier. BILL GUNSTON describes the two XF-88 Voodoo prototypes.

Today the XF-88 is one of the half-remembered early jets that failed to make it. In fact it was one of the greatest ever technical achievements, by the young team at MAC (McDonnell Aircraft Company, St Louis) who had to do it all the hard way as they broke new ground in every direction. The only reason it 'failed' was that nobody could build a jet fighter able to fly thousands of miles as escort to Strategic Air Command's heavy bombers.

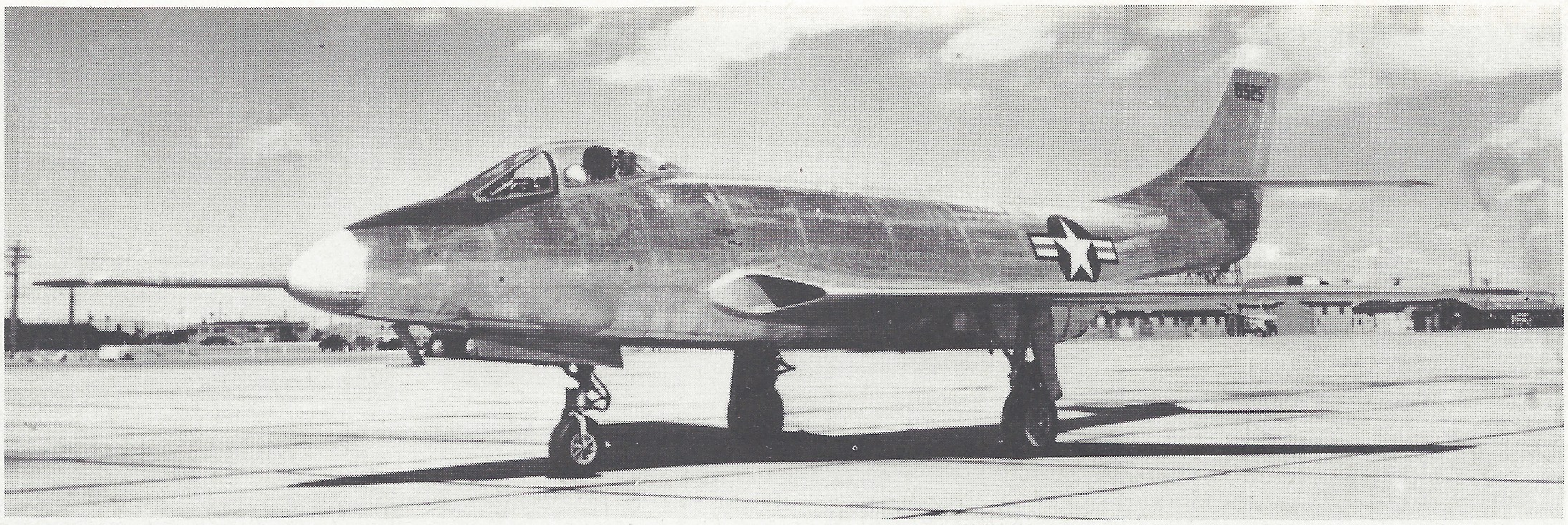
In fact, the 88 was a splendid aircraft to fly. It bristled with features that seem modern today, such as minimum-thickness sweptback wings and tail, twin afterburning engines and irreversible powered controls. The result was a rakish speedster that strongly influenced the drawings of countless excited schoolboys, yet instead of being a feared beast it was unusually free from difficulties. Yet it was designed 35 years ago, when MAC had flown the XFD-1 (not yet FH-1) Phantom and was designing the straight-wing XF2H-1 Banshee!

The thinking behind the new fighter was based on the vital role played by P-51s in protecting USAAF bombers in 1944-45. In August 1945, the USAAF Fighter Branch at Wright Field issued an informal requirement for what they called a 'penetration fighter' to accompany bombers over a combat radius up to 900 miles yet have over-target performance good enough to defeat expected opposition. There were various other stipulated missions, but the crucial one was this combination of fighter performance and range, which in head-on conflict made the design almost impossible. The suggested weight limit of 15,000lb had long before been exceeded by the piston-engined P-47, and for a jet was wishful thinking. One of the other companies that worked on this concept spent 1946 trying to get the weight below 75,000lb!

It seemed reasonable to use two turbojets in enlarged wing roots. This configuration had been used in both the Phantom and Banshee, and gave modest drag with the reliability of two engines and also the extra range and endurance of cruising with one engine cut back to flight idling and the other at maximum continuous power. Most turbojets were temperamental and unreliable, in contrast to today where it is easy to show by statistics that you are less likely to have engine snags with a single-engined aircraft such as the Hawk and F-16. Moreover, MAC was familiar with the slim Westinghouse J34, which had small frontal area, quite good specific fuel consumption and not a bad inflight record.

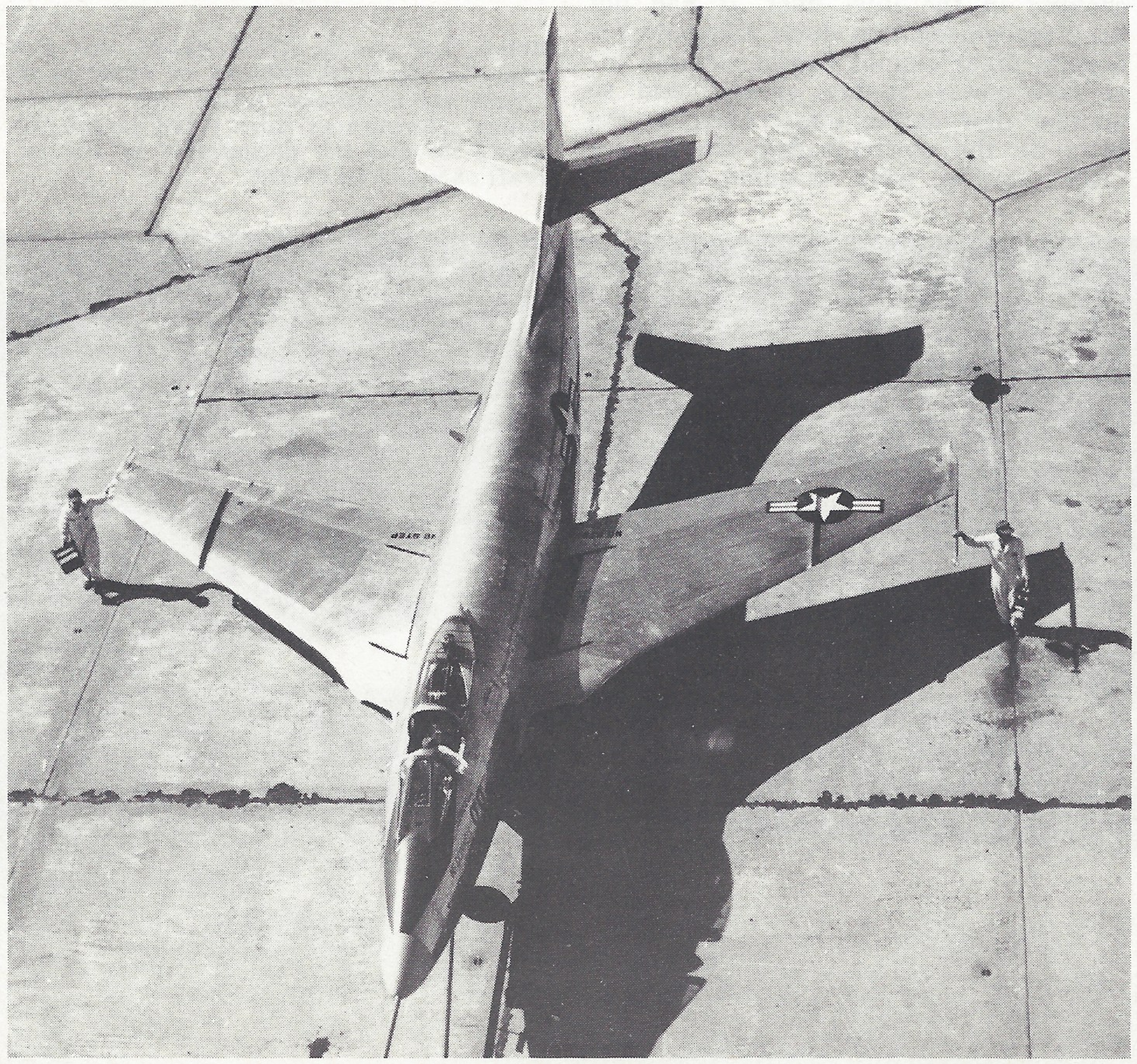
Thus the initial McDonnell Model 36 study looked like a Banshee with stubbier and thinner wings, only 6·5 per cent in thickness and tapered on the leading edge to give 20° sweep even on the 40 per cent chord line. What killed it was the apparent impossibility of getting good high-speed airflow over the deep wing roots, where the strong spar booms (without help from sweepback) added up to much greater depth than in the rest of the wing. The next study hung the engines on the wingtips. This looked great from several points of view, but was killed by the possibility of alarming aeroelastic distortion of the thin wing linking the three widely separated masses of engines and body; rate of roll was also going to be poor, and engine failure on takeoff posed a tough problem.

While these studies were being refined, MAC received microfilm on German swept-wing data. Previous rumours were



All photographs on these pages show the prototype XF-88 46-525. This aircraft was first flown on October 20, 1948, from Muroc Air Base, by Bob Edholm.

replaced by numerical data from German wind tunnels, and in September 1945 the decision was taken to sweep back the wings and tail at 35° at quarter-chord. Other companies, notably Boeing with the B-47 and NAA with the F-86, made the same choice, but MAC accepted the bold thickness ratio of only 7·9 per cent, with a 'laminar' profile with the maximum thickness at 44 per cent chord. Tunnel tests by September 10, showed good results with split flaps in conjunction with a hinged leading edge drooping to 30 degree over the outer wing. Later the tip-stall problem was alleviated by adding 'stall plates' across the wing from the leading edge to the aileron hinge. Today we call such things fences.

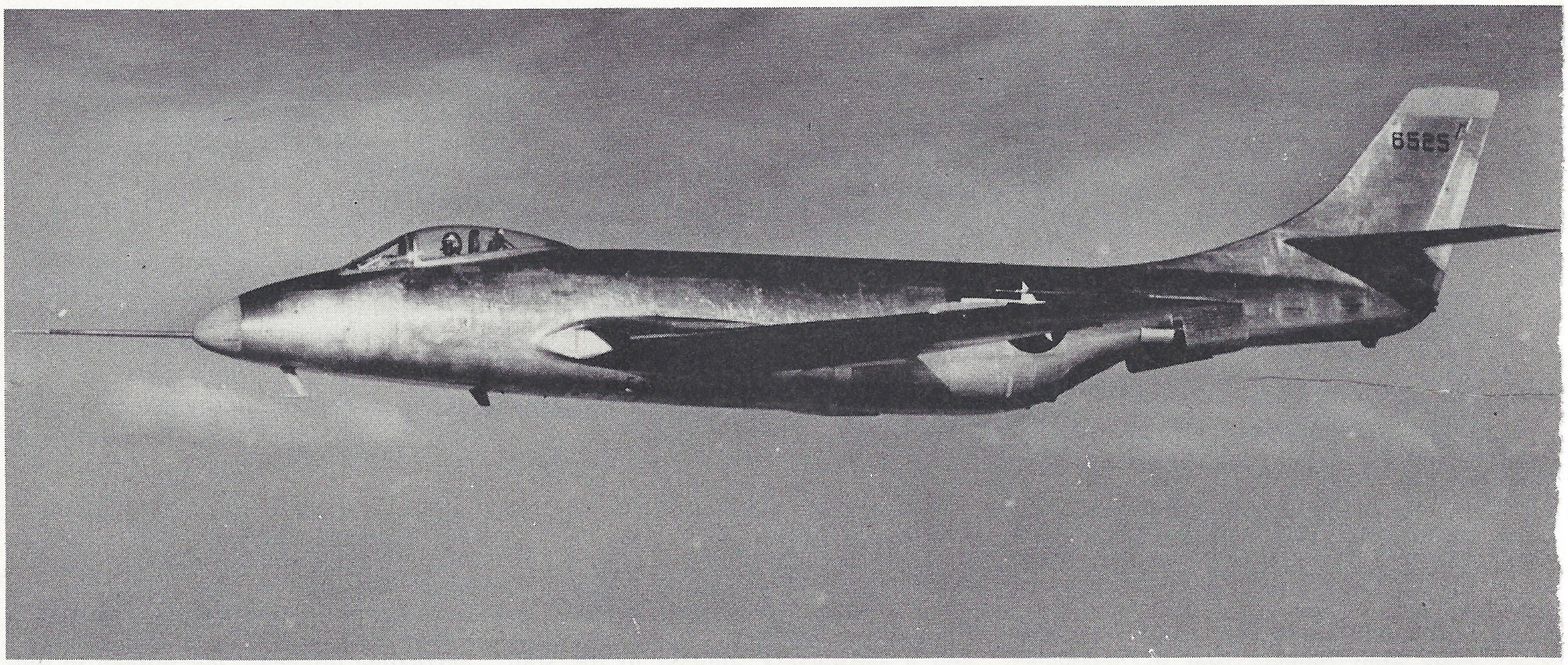


MAC's brilliant team, led by E. M. 'Bud' Flesh, the Model 36 project engineer, under the vice-president of engineering Kendall Perkins, never did find a satisfactory solution to the stall problem with tip tanks. They would have been intrigued to learn that in 1982 drop tanks would just be hung under the body or inner wing on pylons. They did however solve the engine problem by putting the J34s in the fuselage. This left the wing free for high-Mach flight, and by putting the engines as far forward as possible for balance, and right in the bottom of the fuselage for easy engine-change down on to a dolly, a good installation was achieved. The main decision to be taken was whether to put the engine nozzles right in the tail, and eventually it was calculated that weight and thrust-loss would outweigh the distorted fuselage lines resulting from letting optimum-length jetpipes blast through the underside of the fuselage. The latter arrangement caused severe skin temperature and pressure-fluctuation problems, but worked so well it was seen again in the F-3 Demon and F-4 Phantom.

Apart from the nozzles the main problem was where to put the inlets. MAC never departed from wing-root inlets, though studies were made of inlets in the nose and sides of the fuselage. Despite the penalty of some 8 per cent in both fuel consumption and maximum thrust caused by the extra length of the inlet ducts and their double bend, reasonable results were eventually obtained from root inlets with sharp-edged lips swept at 40 degrees and 2in high ramps at the inboard end to divert fuselage boundary layer. Overall pressure recovery at Mach 0·8 was 96·6 per cent, compared with 82·2 per cent for the Venom.

In the mid-1940s the Vee or butterfly tail was popular, and as it seemed to offer a simpler and cheaper solution, a swept Vee tail was on the original Model 36 submission to the AAF in October 1945. Tunnel testing showed poor longitudinal stability near the stall, and adverse roll due to rudder action, which no amount of tinkering could remove. The final choice therefore fell on a swept conventional tail, with the peak thickness of the tailplane well aft of the thickest point on the fin. The tailplane was designed with two spars and numerous ribs, but was then redesigned to a far higher stiffness with only three ribs (root, semi-span and tip) but six spars and thick magnesium skins. Only later was it realised that the increased stiffness was vital in being able to pull high load factors at unprecedented speeds.

Structurally the Model 36 posed colossal problems. Though it was no heavier than a P-47 it had wing and tail surfaces that were thinner, yet dynamic pressure at full throttle was double that of the piston-engined machine. The main difficulty was torsion of the wing, especially with full aileron at Mach 0·85 at low levels. It was eventually made stiff enough, but the required 350 USgal tip tanks posed problems incapable of being



solved. On a rig it was possible almost to break the wing by rhythmically oscillating the nose of the tank by hand. In contrast the deep-keel fuselage, tricycle landing gear with main wheels lying under the inlet ducts, and forward-hinged rear-fuselage speed brakes all matured with no undue difficulty.

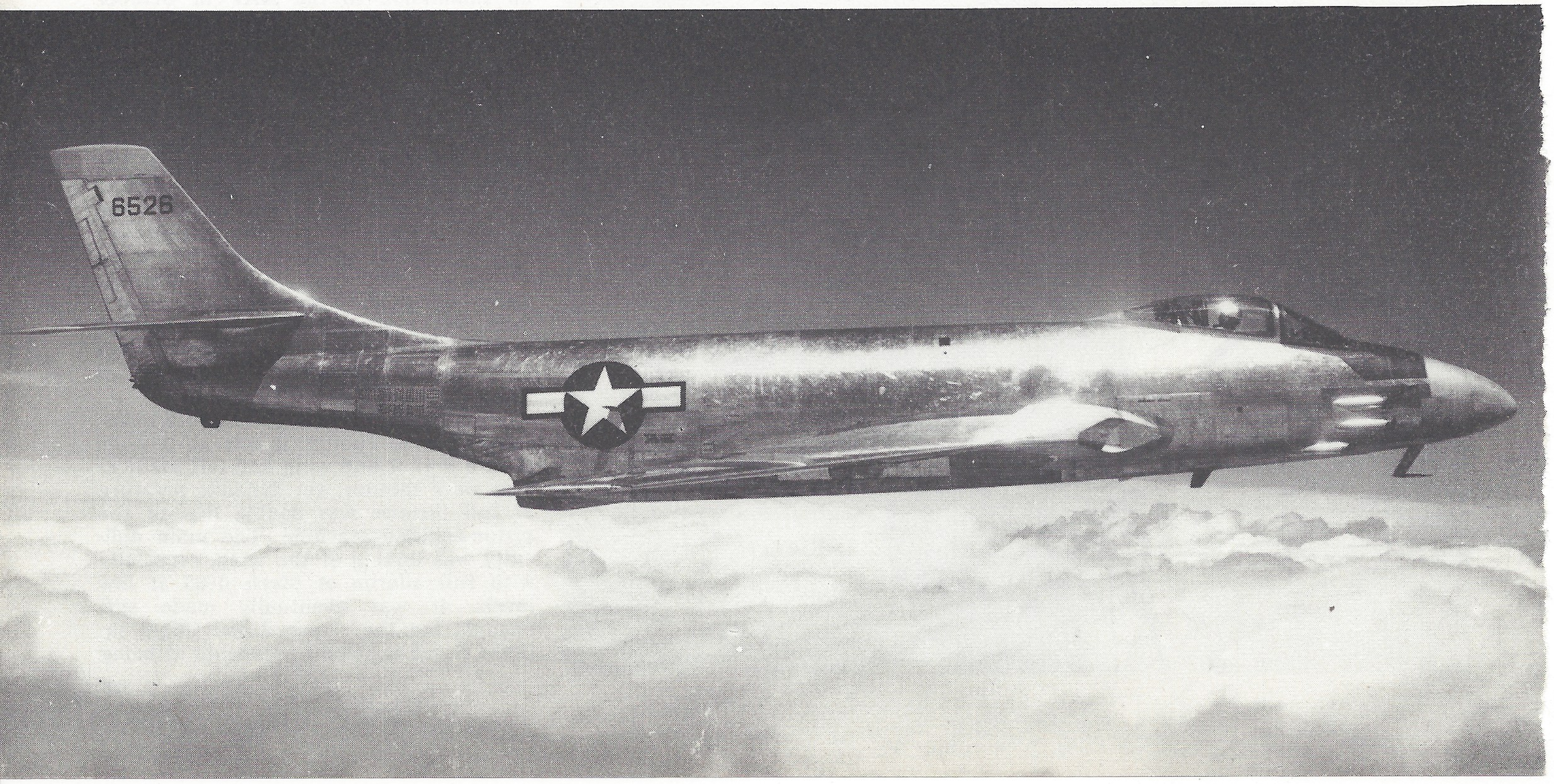
MAC received a contract on June 20, 1946 for two prototypes with designation XP-88 (later XF-88). Tail serial numbers were 46-525 and -526. In parallel, major rigs were constructed to develop the flight control system and armament. The former featured full hydraulic power, with irreversible surfaces, protected by artificial feel responsive to dynamic pressure, and was one of the first three such systems ever designed. As for firepower, this was to comprise six M-24 cannon, with a total of 1,500 rounds of 20mm ammunition loaded electrically by a cunning method which pulled the belts from the ground cart up through the ejection chutes. This did away with ammunition boxes, and the test nose was repeatedly reloaded by two men and readied for firing in 12 minutes. By August 1949 more than 90,000 rounds had been fired. Belly and wing pylons were provided for bombs, rockets and other stores.

The first XF-88, by this time named Voodoo, was flown at Muroc (Edwards) by Bob Edholm on October 20, 1948. The only major snag was a very long takeoff caused by lack of power due to choking in the inlet duct. It had not been recognised that ducts adequate for normal flight cannot handle enough air at full power at low speeds, and so another new device was created in the form of the spring-loaded blow-in (or rather suck-in) door, to admit extra air into the walls of the ducts when needed.

Above, *another view of the unarmed XF-88 46-525. With two 3,000lb thrust Westinghouse J34-WE-13s, the XF-88 was underpowered though its handling and endurance was found to be satisfactory.*

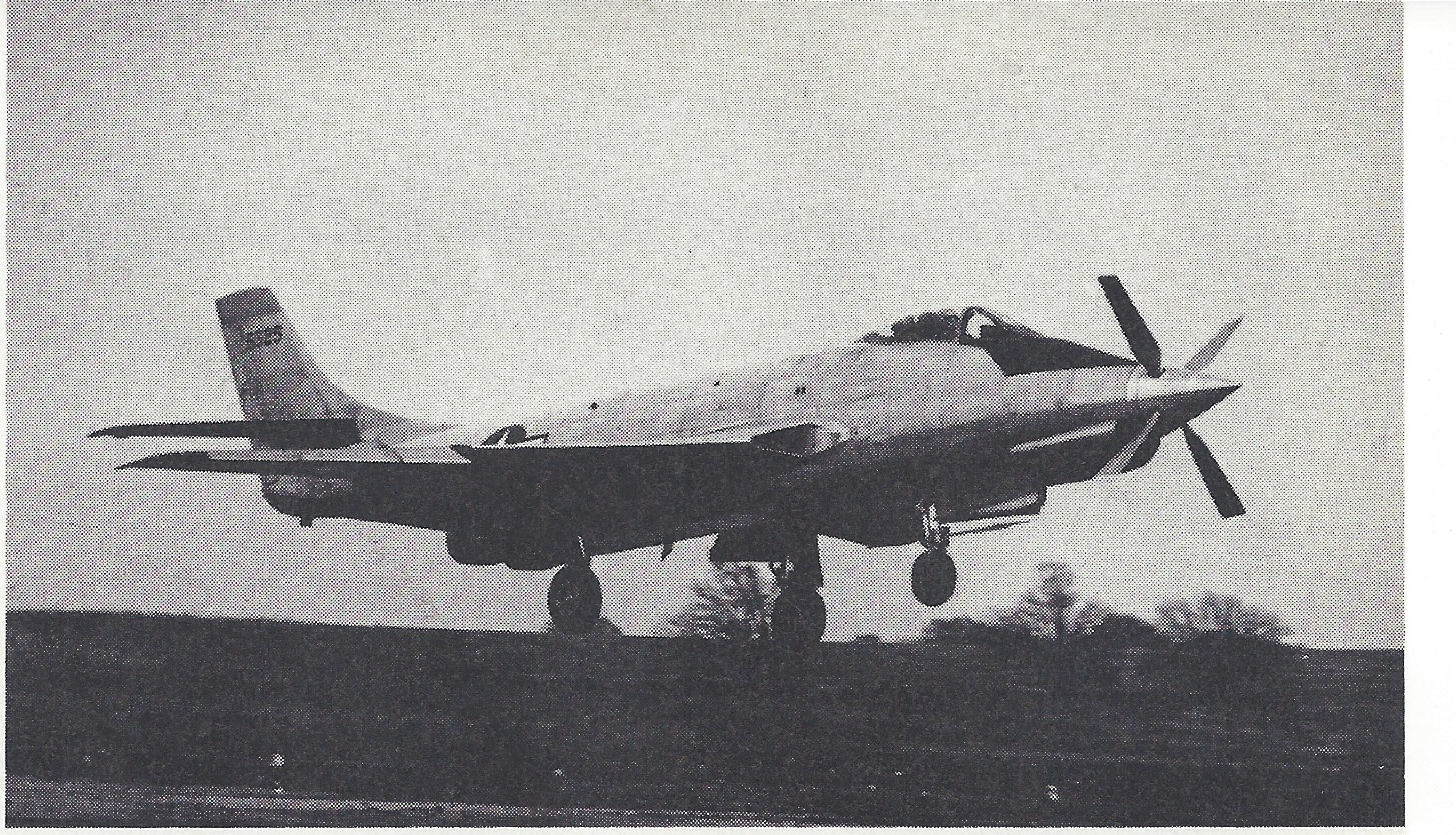
General handling was exemplary, stall characteristics better than predicted, and in the first quarter of 1949 the process began of nibbling a little further up the Mach scale with every flight. Pitch-up or tuck-under (the latter had been suggested by tunnel models) was not encountered, and the limit

Below, *the second XF-88, 46-526, was first flown on April 26, 1949. In an effort to increase its maximum speed two Westinghouse afterburners were fitted to the XJ-34-WE-13s and the designation of the aircraft changed to XF-88A.*

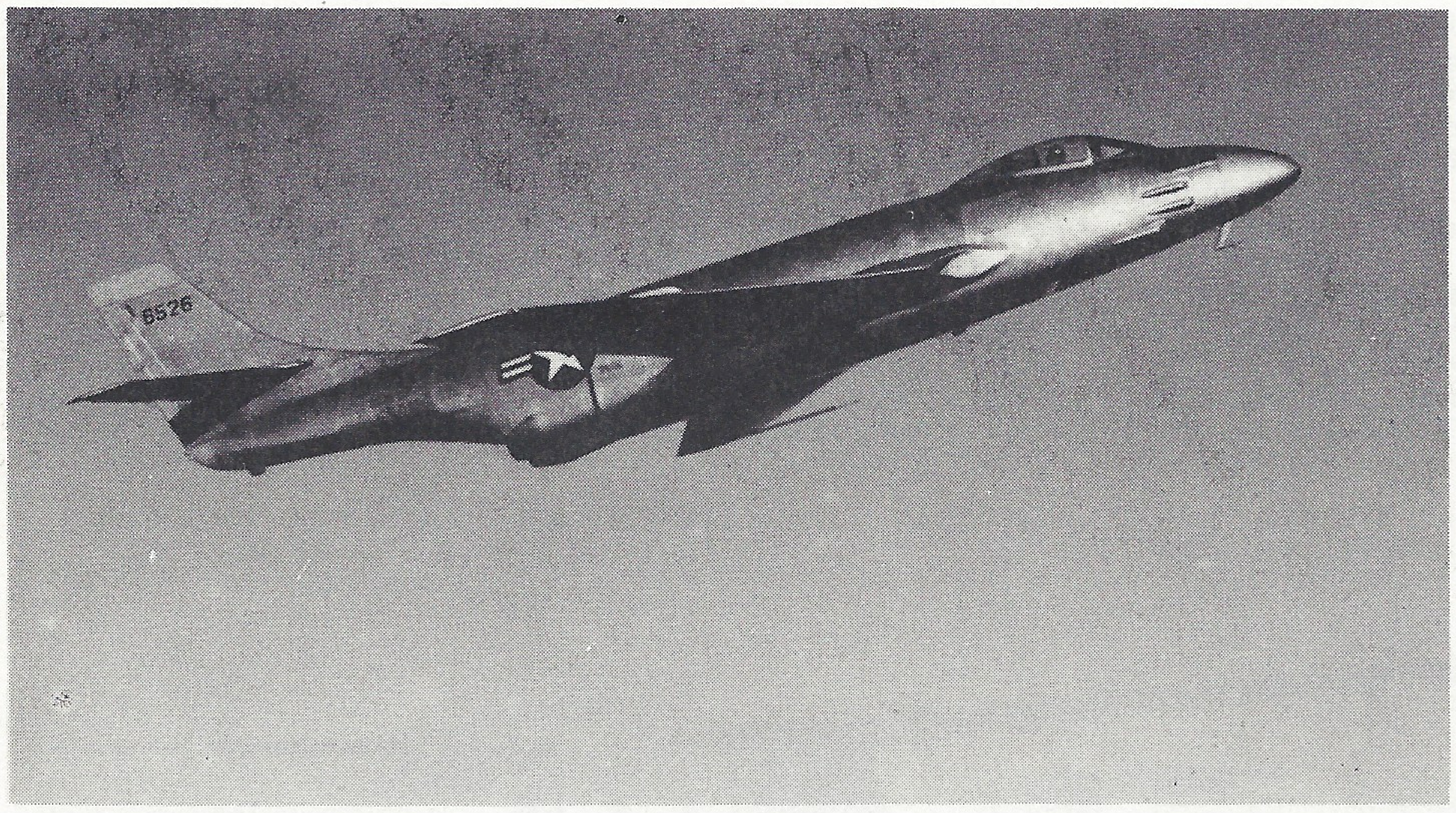


appeared to be reached with the original engines on Flight No 70 on May 12, 1949. The aircraft rolled over at Mach 0·82 at 41,000ft at full power and made a split-S dive, initially pulling 2g and finally recovering to level flight at 18,000ft at 3·4g. In the vertical portion of the dive the airspeed reading could not be relied upon, but both the VSI (vertical speed indicator) and test instrumentation recorded a rate of descent of 67,600ft min. This corresponded to a Mach number of about 1·17-1·19 depending on precise air temperature. There was not the slightest buffet, trim change, flutter or yaw.

Back in summer 1946, the MAC engineers had realised that this aircraft was an ideal choice for thrust boosting, the preferred arrangement being afterburning. This was then a very new idea, hardly beyond the stage of ground test rigs and posing very severe problems with combustion, metal failures due to sheer temperature and the need to have a nozzle of variable profile and area.



Above, *the prototype XF-88, 46-525, was later fitted with a 2,650 h.p. Allison XT-35-A-5 for research into transonic and supersonic propellers. The Westinghouse turbojets were retained throughout the test programme.* **Below left,** *another view of the XF-88A. Flight trials of this aircraft were completed in June 1950.*



XF-88 data

Dimensions	
Span	39ft 8in
Length	54ft 1½in
Height	17ft 3in
Wing area	350 sq ft
Weights	
Empty weight	12,140lb
Gross weight	23,100lb
Performance	
Max speed/sea level	641 m.p.h.
Cruising speed	527 m.p.h.
Climb to 35,000ft	14·5min
Service ceiling	36,000ft
Range	1,737 miles

With the XF-88 an added problem was the restriction on afterburner length to 52in, less than half the common amount. Engine companies and specialist jetpipe firms universally declined to become involved. That might have been the end of the matter had not MAC gained some experience with ramjets and pulsejets for small helicopters. In December 1947 the contract was changed to include afterburning engines in No 2 aircraft which became the XF-88A. MAC went ahead and developed its own afterburner for the J34 engine, and it was staggeringly modern in almost every respect. Not only did it fit well within the 52-in length but instead of the prevailing crude clamshell it had a variable-profile iris nozzle with 48 zero-leakage flaps positioned by a translating ring precisely similar in form to modern afterburner nozzles. Static augmentation of 34 per cent was achieved, and by varying the nozzle shape in the cruise regime the range and endurance at low altitudes were extended by 31 per cent.

The afterburning XF-88A flew on dry J34-WE-13 engines on April 26, 1949, tested afterburner operation with a WE-15 in the left-hand position on June 9, and eventually achieved almost exactly Mach 1 on the level with two Dash-15 engines.

Production hopes dashed

By August 1949 a production run of 108 F-88As priced at $457,204 each was being negotiated. Thus, the whole run would have cost as much as a single F-18 Hornet. I do not have room to go into the two forced landings of the XF-88A, the thrilling rides at Muroc by much-decorated USAF test pilots or their very high opinion of the Voodoo. The trouble was, that there was no money, and by the start of the Korean war in June 1950 the whole concept of a penetration fighter had been abandoned. Operations at Muroc were suspended on August 4, 1950, and a month later MAC was informed by letter that their bird had rated No 1 of all those evaluated.

That is not quite the end of the story. In January 1952 the Air Research and Development Command searched for an aircraft on which to test propellers designed for supersonic flow over the blades. One choice was the XF-88 (ship No 1), which was fitted with an Allison T38 turboprop in the nose, fed by two chin inlets for the compressor and oil cooler, and at first driving a 10-ft four-blade Curtiss experimental propeller. The engine power section was on the left and the nose landing gear moved to the right, the propeller being on the centreline. Most of the testing was done by NACA at Langley Field, the three-engined aircraft being redesignated XF-88B.

These early supersonic propellers were inefficient and excruciatingly noisy, but the XF-88B did very well. By the time it began its new role at Langley on April 14, 1953 the same basic design had been resurrected with much more powerful engines as the F-101, still called Voodoo. The first of these flew on September 29, 1954, and as you read this Voodoos are still thundering aloft with the Canadian Armed Forces.

Next month: Bill Gunston describes the Martin XB-48.