REPUBLIC AVIATION – Its Rise and Fall

Part 6: F-84 Users, and Experimental Jet Fighter Developments

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The F-84 family – starting with the straight-wing Thunderjet and going through to the swept-wing Thunderstreak and Thunderflash – was a successful series of designs, if measured in terms of output. By the time the last RF-84F rolled off the production line in 1958, nearly 8,000 of all versions had been built. During this period, Republic was aware of the need for continuity of future production, and it undertook to design some highly experimental military fighters for the perceived needs of the USAF. This instalment looks at the F-84 as supplied to operators other than the USAF, and also at its next two designs, the unconventional XF-91 and XF-103 fighters.

F-84 Users and Export Customers

Republic produced the F-84 series primarily for its main customer, the USAF. It served extensively with Strategic Air Command and Tactical Air command, in addition to a brief period with Air Defense Command. It was also used by Air Training Command, the Air National Guard, and the Air Force Reserve. Evaluation of the type by the US Navy took place in 1949, but this did not result in an order. However, Bureau of Aeronautics serial numbers were allocated for eighty drone conversions of F-84Bs to F-84KX, although it is unclear if all the conversions went ahead.

Many of the F-84s built were destined to be supplied to friends and allies of the United States, and particularly those countries forming membership of NATO. They were mainly issued under the Mutual Assistance Program (MAP) or Mutual Defense Aid Program (MDAP).

Later straight-wing Thunderjets, essentially F-84E and F-84G models, were supplied to Belgium, Denmark, France, Greece, Italy, Iran, Netherlands, Norway, Portugal, Taiwan, Thailand, Turkey and Yugoslavia. Swept-wing F-84F Thunderstreaks were exported to Belgium, France, Greece, Italy, Netherlands, Turkey and the Federal German Republic. The final production version, the photo-reconnaissance RF-84F, was widely used by the air forces of Belgium, Denmark, France, Greece, Italy, Netherlands, Norway, Taiwan, Turkey and Federal Germany.

In spite of a long history of development issues and problems, the F-84 series was extensively produced, both for the US military and for export. A total of 7,883 of all variants was built, comprising 4,457 straight-wing Thunderjets, 2,711 F-84F Thunderstreaks and 715 RF-84F Thunderflashes. From the first flight of the XP-84 on 26 February 1946 to its eventual retirement as a type – when the Hellenic Air Force flew the last sortie of the RF-84F Thunderflash on 29 March 1991 – the F-84 series had been flying for a little over forty-five years with the air forces of fifteen mostly Western nations.

Republic XF-91 Thunderceptor

Development of the F-84 series was a massive programme for Republic, and would

Heading photograph: Designated the F-84KX and designed to be used by the US Navy as an unmanned drone, this type was modified from the USAF F-84B. The one illustrated carries the BuAer. No. 142270, from a batch of 80 which ran from 142269 to 142348. Below: F-84F Thunderstreak of 6° Stormo, Aeronautica Militare Italiana, getting airborne with a pair of 375 US gallon underwing fuel tanks, and armed with twelve 5-inch HVARs beneath the outer wings

occupy the company well into the 1950s. However, in spite of this, there was scope for additional work, and following a request for proposals by the USAAF in 1946 for a fast, high-altitude interceptor, Republic began designing what would become the XP-91. Superficially, this resembled the F-84 with swept wings, but Republic's concept was highly innovative in many areas.

Initially, the XP-91, later re-designated XF-91, was envisaged as a single-jet, single-seat fighter, powered by a General Electric J47 turbojet fitted with reheat. In the event, this did not provide the power that was required to ensure the desired supersonic performance. As a means of adding to the dry thrust of 5,200 lb (23.1 kN) or reheated thrust of 6,100 lb (27.1 kN), it was decided to add rocket propulsion in the form of a Curtiss-Wright XLR27 motor, which would add 13,000 lb st (57.8 kN).

This substantial engine – both in terms of size and power output – was far from being a fully-developed design and was giving General Electric problems which were not likely to be sorted out in the short term. As a contingency measure, to ensure that the XF-91 programme could proceed smoothly, it was decided that something less experimental should be used, and Republic settled on a smaller, lower powered engine. This was the Reaction Motors XLR11, a four chamber unit producing 6,000 lb thrust (26.7 kN). It had already proved itself in use, powering the Bell X-1 to become the first aircraft intentionally flown faster than Mach 1 in level flight.

The change of rocket power plant resulted in a redesign of the rocket chamber layout. Originally the XLR27 chambers were set in vertical alignment, two above and two below the turbojet exhaust, but with the new XLR11 engine, all four chambers were contained in an enlarged fairing beneath the jet exhaust in a diamond pattern.

As a result of these changes, the XF-91 became a mixed-power rocket and turbojet aircraft, and the only US fighter to have this combination (other than the use of RATO or rocket power for zero-length take-off launches). The result was a significant improvement in performance, with a top speed of Mach 1.49 at altitude, a ceiling in excess of 50,000 feet, and the ability to reach that height in a little over five minutes.

Above: This view of the second prototype XF-91 shows the planform of the wings to good effect. The widest part of the wing chord can be seen to be nearest to the tips

Above: Prototype XF-91 46-680 with its original nose intake and a conventional tail fitted. The tandem mainwheels are clearly apparent in this view. Below: Second prototype XF-91 46-681, fitted with a nose radome, conventional tail, and carrying two 541 US gallon underwing fuel tanks

The resultant fighter was a good example of a point-defence interceptor, in the manner of a concept started by the Messerschmitt Me 163, and it bears an interesting comparison with Britain's attempt at a mixed power interceptor, the Saro SR.53. In one fundamental way, the US design differed from the British one, in that it was essentially a jet fighter augmented with rocket propulsion to achieve its required performance, whereas the British design was primarily a rocket-propelled fighter, but fitted with a low-power turbojet as a sustainer to cope with the limited duration of the main power plant.

Eventually, neither concept flourished and both were replaced by more conventional jet-powered designs. In the US, with a near-continental size land mass to defend, the idea of a point-defence interceptor gave way to one of area defence, and a later generation of conventional fighters evolved – including the F-101B Voodoo, F-102A Delta Dagger and F-106A Delta Dart – to address this philosophy.

Republic Aviation was contracted to produce two prototype XF-91s (46-680 and 46-681) and the first of these had its maiden flight on 9 May 1949 from Muroc (later renamed Edwards Air Force Base). The 40-minute flight was made on turbine power alone, as a rocket engine had yet to be installed. Neither prototype was fitted with armament, although intended provision was for four 20-mm cannon or twenty-four 2.75-inch Mighty Mouse AARs. It was also envisaged that four AIM-4 Falcon AAMs could be fitted.

The wings of the XF-91 were highly swept – a new design concept at that time – with attendant aerodynamic problems, not least that of tip stall. Typically the stall occurs first at the outboard wing, causing the centre-of-lift to move forward, often with resultant sudden and violent pitch-up. This led aircraft designers to consider a variety of design solutions including wing fences to stabilise the outward flow of the boundary layer (particularly prominent in Soviet designs in the nineteen-fifties), or leading edge dog-tooth extensions (as seen on the British Hawker Hunter).

Republic's solution was to employ inverse taper of the wing chord, meaning that the distance from leading to trailing edge increased progressively towards the wing-tip, in contrast to more conventional wings where the chord decreases. The result was that the wing stalled inboard first, causing a more gentle pitch-down. A further benefit from this wing layout was to improve the drag characteristic at the root-to-fuselage join.

A consequence of the unusual wing planform was that the space available for main landing gear stowage was limited in the wing roots, but there was more space available outboard. As a result, the undercarriage retracted outwards into the wing's outboard sections, which necessitated the use of a pair of small mainwheels in tandem. The positioning of the undercarriage attachment points at mid-wing did allow provision for wing pylons on the inner sections, including carriage of external fuel tanks which were large enough to contain up to 541 US gallons (451 Imp gallons; 2,049 litres).

In addition to its unconventional plan shape, the wing was remarkable in another aspect, namely that it had a variable incidence capability. This was manually controlled through –2° to +6°, to allow the wing incidence to be increased on landing so as to avoid a high angle of attack with the consequent result of the pilot losing sight of the forward horizon. This feature worked well and was successfully tested on a number of flights. It was also envisaged that the variable-incidence wing would contribute to increased combat manoeuvrability, although this feature was not developed.

Finally, regarding the advanced features of the wing, full-span leading-edge slats were fitted, giving the XF-91 an exceptionally good low speed capability, such that it was often left behind by chase planes desperately struggling to stay airborne.

When the XF-91 was conceived, the designers had planned to fit a 'V' shape, or 'butterfly'-type tail comprising two tailplane surfaces with a high dihedral angle and no

Above: A view of the prototype, 46-680 at altitude, carrying a pair of 541 US gallon external fuel tanks. The configuration of the rocket engine fairings suggest that these are vertically aligned with two rocket ports above and two below the jet pipe, as arranged for the XLR27 engine which was never fitted

Left: The second prototype, 46-681, undergoing maintenance, and like the photo above, also configured for the XLR27 rocket engine. The four rocket pipes can easily be seen above and below the jetpipe. The mainwheel undercarriage doors located close to the wing tip are easily visible in this view

Below: This shows the second prototype in a later configuration. It now has the XLR11 engine in the lower fairing which has been widened to accommodate the rocket pipes in a diamond arrangement. Also, the conventional tail surfaces have been replaced by a 'butterfly' arrangement. Smaller, 230 US gallon external fuel tanks are fitted in this image

Above: The two XF-91 prototypes, 46-680 on the left, in its final configuration with a radome fitted to the nose, above a modified chin-type intake. On the right is 46-681, now fitted with a 'butterfly' tail. Between them, in the background, is the YRF-84F Thunderflash prototype

fin/rudder. Elevators on the tailplane would control the aircraft in pitch and yaw. This was, of course, an unusual design aspect, and one eschewed by the engineering department at Republic. As a result, both prototypes were completed with conventional tail surfaces. However, the second prototype was eventually fitted with a 'butterfly' tail at the insistence of the USAF, and it was found to create less of drag than a conventional empennage.

At a later stage of the development of the XF-91, at different times, each prototype was fitted with a nose radome, and the circular air intake was modified to a chin configuration. As such, the first airframe has survived and is now displayed at Wright-Patterson Air Force Base.

Ultimately, no orders were placed for the XF-91, and the two airframes continued to be used for testing, particularly of the variable-incidence wing, until 46-681 was lost in an accident. A proposed all-weather variant, the F-91B failed to proceed after it was submitted in competition with other designs including the Republic design which became the XF-103.

Below: Artist's impression of the high speed XF-103 interceptor showing clearly its small delta shaped flying surfaces and its faired cockpit canopy. A large engine intake is visible on the fuselage under-surface below the wing leading edge

Thus ended a programme which had been full of innovation, and had proceeded without major issues. It failed to reach production only because the USAF did not consider the concept of a point defence fighter to be the way forward, and it gave way to aircraft of later design technology and which met the USAF's need for area defence interceptors.

Republic XF-103

The USAF, charged with the defence of the United States against aerial attack in the nuclear age, faced an enormous task, given that the land area involved was on a continental scale, with major cities and other targets being spread widely. Attack from the only potential enemy of any significance would be from the USSR across the Arctic, with the northern wastes of Canada acting as a buffer to provide a short breathing space, provided that the early warning systems were effective.

In this scenario, short-range or point-defence interceptors of the kind represented by the XF-91 offered little security, and the USAF turned to a strategy of area defence involving fighters of high capability, but with a more significant range. Thus, in 1950 the USAF issued a request for proposals (known as MX-1554) for a long-range, high-performance, 'all-weather' interceptor, capable of meeting the new defence philosophy. This was to be coupled with a sophisticated fire-control system being developed by Hughes and it would integrate with the USAF's Semi-Automatic Ground Environment (SAGE) air defence system. The proposed new fighter would operate together with the F-104 Starfighter, the latter being seen as a short-range component to supplement the new design in an overall defence system

As a result of MX-1554, several possible designs were submitted by six companies. For its part, Republic offered three proposals. The first was the F-91B rocket-powered fighter. Next, there was a ramjet-powered aircraft, Republic's preferred choice, and destined to become the XF-103. Finally, Republic offered a conventional turbojet-powered, Mach 2 fighter, which it considered to be a fall-back option in the event of failure of the other two designs.

Ultimately, the MX-1554 competition was won by Convair, with its delta-wing F-102A, itself considered to be an interim design, pending introduction of the Convair F-102B, later re-designated F-106A. In spite of the Republic design losing out, the USAF was still interested in the concept of a turbo-ramjet fighter, and it continued to provide funding to Republic to keep the XF-103 project going.

The XF-103 was a large aircraft by fighter standards, with a fuselage length of 74 ft (22.6 m) and a wing span of 36 ft (11.0 m). Wings were set at mid-point from a plan view, and mid-height on the fuselage. Tail surfaces were a conventional layout, all-delta in shape. The engine intake was set on the under-surface of the fuselage, and fed the advanced turbo-ramjet which exhausted through a jet pipe at the rear. The cockpit was set into the fuselage without a raised canopy, and two faired windscreens, one each side, afforded some lateral and restricted forward vision. It was proposed to provide forward vision by means of a periscope, and this was tested extensively in a modified Republic F-84G. Over time, the visibility was more and more restricted on the F-84G to represent as closely as possible the visibility afforded by the XF-103 with its periscope and faired wind-screens, and it was found to be satisfactory.

Above: F-84G Thunderjet 51-843 flown experimentally with a periscope which was intended to be incorporated in the XF-103

The power plant was a combination of a conventional turbojet and a reheat system modified to act as a ramjet at higher operating speeds. The design was envisaged as a Mach 3+ interceptor, and at that speed a normal turbojet would not be able to operate without considerable modification to the jet engine intake system.

The basis of the power-plant was a Wright YJ-67 turbojet, developed under licence from Bristol Siddeley's 9,800 lb thrust (43.6 kN) Olympus 1/2 turbojet. Coupled to this would be a Wright XRJ-55 ramjet. Essentially, the ramjet was the reheat section of the YJ-67. Initially, the XF-103 would take off and fly up to Mach 2 on turbojet power of some 15,000 lb (66.7 kN) with reheat. Above Mach 2 the intake air would bypass the turbojet, and be diverted straight to the reheat system which would effectively become a ramjet generating up to 30,000 lb thrust (133 kN). At this power, a top speed of Mach 3 plus would be achieved at an altitude of up to 75,000ft.

Because of the high-speed operating profile of the XF-103, normal aluminium construction was not possible and the airframe was, essentially, titanium, a new material for aircraft at this time.

Armament was proposed as six Hughes GAR-1 Falcons, plus, initially, a battery of thirty-six 2.75-inch Folding-Fin Aircraft Rockets (FFAR). The latter were deleted from the specification at a later date, making the armament a guided missile system only.

Given the high-speed specification of the XF-103, a pilot's escape system was developed comprising a capsule with a sliding hood which completed the enclosure and maintained pressurisation at the time of ejection, but otherwise remained open to enable the pilot to reach the cockpit controls. Ejection would be downwards, and stabilising fins and a drogue parachute would be deployed. At 20,000 ft and at speeds under 260 kt (480 km/h), the main parachute would emerge. The capsule also worked as an elevator to facilitate crew access into the cockpit from ground level.

Development became an increasing issue for the XF-103, a design that had originated in the early 1950s, and by 1953, only a full scale mock-up had been produced—although work had commenced on an actual prototype. It was anticipated that a flying prototype would not be available before 1960, in spite of development costs reaching $100million by 1957.

At this point, with no plans to put it into service, the USAF decided to withdraw funding and cancel the project. As well as a protracted gestation, and the ability to devour funding on a colossal scale, indications were that the revolutionary power plant configuration was not likely to produce the promised amount of thrust. Consideration was given to replacing it with a BS Olympus engine of 20,000 lb (89.0 kN), but in the event, this was not proceeded with. Following cancellation of the project, the airframe under construction was scrapped.

Thus ended a period of extraordinary technological development by Republic to produce a high performance interceptor—first as a mixed-fuel aircraft in the F-91, and then as a mixed turbo/ramjet with the F-103. Both explored radical design features, and each was indicative of how fast military designs were evolving in the immediate post-war era. In the end, in spite of the progress made and the money spent, neither design went into production, and Republic was left looking to its next design, the F-105 Thunderchief, to sustain the company.

Next Edition

We will look in detail at the F-105 Thunderchief, which would become the mainstay of fighter-bomber operations in the Vietnam War, and the merger of Republic with Fairchild-Hiller.

Above and below: Two views of the full-size mockup of the XF-103. The upper picture shows the escape capsule which formed an elevator for crew access, located on the ground beneath the faired windscreen