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THE DEVELOPMENT OF UNITED STATES AIR FORCE FIRST GENERATION JET FIGHTER AIRCRAFT, 1941-1950

by

Thomas J. Goetz

Volume I

A dissertation submitted to the Graduate Faculty in History in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2001

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This manuscript has been read and accepted for the Graduate Faculty in History in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

THE DEVELOPMENT OF UNITED STATES AIR FORCE FIRST GENERATION JET FIGHTER AIRCRAFT, 1941-1950

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Thomas J. Goetz

Adviser: Professor David Syrett

The gas turbine, or jet engine revolutionized air combat. Invented by an officer in England's Royal Air Force, and first used to power combat aircraft by Nazi Germany, the jet engine would be perceived by the United States Air Force as the most important technological development of World War II. Although a relative latecomer to the field of jet propulsion, the Air Force quickly developed a virtual obsession with the technology. During the war, the Air Force made numerous attempts to develop a useable jet fighter, culminating in the graceful and effective Lockheed P-80 Shooting Star. Following the war the Air Force used the still rapidly developing jet engine to power a wide variety of combat aircraft, including many new fighter designs. Of these, the most effective would prove to be Republic's F-84 Thunderjet and North American's F-86 Sabre. The Sabre would be the first American combat aircraft to incorporate swept wings to increase its speed, and also the first to exceed the speed of sound. The process of designing and building these aircraft would be one of the first and most important steps in the creation of what would come to be known as the "military industrial complex." Many of these aircraft would eventually be tested in combat in the frigid skies over the Korean peninsula, and would prove to be a vital element in the American success during the Korean War.

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ACKNOWLEDGMENTS

This dissertation could never have been completed without the love, support, and encouragement of my parents, James and Nell Goetz. Thanks, mom and dad.

My first reader, Dr. Kathy Williams, and my advisor, Dr. David Syrett provided not only encouragement and support, but much constructive criticism and useful guidance, and this manuscript is much the better for it.

Others have read this work and offered useful comments and suggestions. Dr. Patrick Abazzia helped shape the basic idea, back when it was in its formative stages. Dr. Al Nofi offered many insightful comments as well.

My very good friend, Captain Les' Melnyk, read through the entire manuscript, despite many other demands on his time, and caught many overlooked errors and logical lapses. I'm grateful for his efforts and help with the project, and for the improvements that resulted.

The Office of Air Force History, especially the Library and its staff, were exceedingly helpful in obtaining source material and pointing me to important sources of information. This project would not have been possible without that help.

The National Archives, both the Documents and the Still Photographs collections, provided tremendous assistance as well, with excellent and helpful staff and much material to improve the research.

The Archives Division of the Air and Space Museum of the Smithsonian Institution provided useful documents and information.

Two corporations provided documents and photographs that contributed to this project as well. Northrop-Grumman provided material on their F-89 Scorpion aircraft, and the Jet Propulsion Division of General Electric donated much useful material about their early jet engines.

A number of individuals contributed their knowledge and in some cases, materials to the success of my work. Edward Marek, an employee of Bell Aircraft, provided much useful material on the Bell P-59 aircraft. David M. Carpenter donated a copy of his book ***Flame Powered***, the story of the development of the P-59. Ken Chilstrom and Nathan Rosengarten sent me a copy of their book ***Test Flying at old Wright Field***, another useful source. Donald Lopez, Deputy Director of the Air and Space Museum and a former Air Force test pilot who flew many of the planes written about here, graciously consented to be interviewed about his experiences.

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Table of Contents
Volume I

Chapter 1	Introduction and Basic Principles	1
Chapter 2	Foreign Innovations	21
Chapter 3	America Enters the Jet Age: The P-59 Airacomet	82
Chapter 4	America's First Combat Jet: The P-80 Shooting Star	112
Chapter 5	Additional American Wartime Jet Fighter Developments	175
Chapter 6	Post-War Influences on Jet Development	232
Chapter 7	Coming of Age: The P/F-80 Matures	268
Chapter 8	Problem Child: The Development of the F-84	319

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Table of Contents
Volume II

Chapter 9	The Shape of the Future: The Development of the F-86	371
Chapter 10	"Neither Snow nor Rain nor Gloom of Night...": The Development of All-Weather Interceptors	416
Chapter 11	Buck Rogers Meets Rube Goldberg: Experimental Jet Prototypes	475
Chapter 12	Growing Pains: An Evaluation of the Development and Procurement of the Early Air Force Jet Fighters	529
Chapter 13	Trail By Fire: U.S. Air Force Jet Fighters in the Korean War	553
Appendices		629
Bibliography		655

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List of Illustrations
Volume I

Chapter 1	Early jet engines	13-20
Chapter 2	German and British wartime jets	59-81
Chapter 3	P-59 Airacomet	103-111
Chapter 4	P-80 Shooting Star prototypes	166-174
Chapter 5	World War II jet prototypes - XP-67, XP-79B, XP-81, XP-83	217-231
Chapter 6	Jet fighters and bombers of the post-war Air Force	266-267
Chapter 7	Post-war production models of the F-80	311-318
Chapter 8	Prototypes and production models of the F-84	357-370

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List of Illustrations
Volume II

Chapter 9	Prototypes and production models of the F-86	407-415
Chapter 10	Prototypes and production night fighters - XF-87, F-89, F-94	451-474
Chapter 11	Jet prototypes - XF-85, XF-88, XF-90, XF-91, XF-92, XF-93	504-528
Chapter 12	No illustrations	
Chapter 13	Operations, battle damage and maintenance on US jets in Korea	612-628

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"Why not incease the compressor compression ratio and substitute a turbine for the piston engine?"
Sir Frank Whittle, inventor of the jet engine[1]

Chapter 1
Introduction and Basic Principles

One of mankind's oldest dreams has been to fly. The dream of setting aside the pull of gravity and soaring with the birds has fascinated humanity for thousands of years. From the legend of Icarus to the sketches of Da Vinci to the early hot air balloons, we have looked to the sky with wonder and longing. But only within the last century have we truly realized that dream.

For inspiration on flight, man has looked mostly to birds, the largest and most observable of nature's aviators. The dream of human-powered flight by emulating the means by which most birds fly, flapping their wings, goes back at least to the Greek legend of Icarus. Unfortunately, many specialized physical adaptations are required of birds to enable them to fly in such a fashion, adaptations such as hollow bones and an enhanced metabolism which are unavailable to humans. Repeated attempts to fly in such a fashion led only to tragedy. Eventually, some individuals began to study certain types of birds whose flight patterns offered more hope for human emulation.

These were the soaring birds, such as eagles, hawks, gulls, albatrosses and vultures. All of these birds can remain in the air for extended periods of time with minimal movement of their wings.[2] By far the most successful of these, the albatross, can fly around the globe without landing on either land or water. These feats intrigued many people, some of whom began to search for ways to do the same. One of the first of these was an Englishman, George Cayley, who in 1810 wrote a pioneering paper entitled *On Aerial Navigation*, about his studies of various

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soaring birds.[3] It was Cayley who first analyzed the primary principle that makes flight possible - *lift*.

Lift is a property of physics, in the realm of fluid dynamics. Although we are used to thinking of the air as gaseous, air possesses the physical properties of a fluid just as water does. The basic nature of the phenomenon of lift is relatively simple, and had been first expressed as a principle, or Law, by Daniel Bernoulli in 1783.[4] The core of the concept is that increasing the velocity of a fluid decreases the pressure it exerts. If a fluid flow around an object moves faster on one side than the other, the slower moving side will have the greater pressure. That higher pressure will push the object in the direction of the lower pressure. This can be easily demonstrated by holding two pieces of paper about an inch or two apart, and then gently blowing between them. Rather than moving further apart, as one might guess, instead they move closer to each other. This is due to the reduced pressure between the sheets. The now greater pressure on the outside of the sheets pushes them together. The pieces of paper will remain in that position as long as the air is moving. As soon as the blowing ceases, the pieces of paper move back apart.

For the purpose of flight, Bernoulli's Law can be employed to generate lift. A shape that has come to be known as an *airfoil* can be passed through a fluid - in this case air. An airfoil is flat on the bottom and curved on the top. Since the curved top is longer than the flat bottom, this shape means that in a given length of time the air moving over the top surface must travel faster than that moving over the bottom. The pressure on the bottom surface is therefore greater than that on the top. As a result, the wing of an airplane does not glide over the air, but rather is pushed up from underneath by pressure differentials. Airfoils can be used for other purposes as well. Inverted, with the flat side on the top, they are known as spoilers. Used in this fashion on

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high performance racing automobiles, the downward pressure is used to make sure the car remains firmly on the ground at speeds which might otherwise lift it from the road, with disastrous results.

A German engineer, Otto Lilienthal, was one of the first to make use of this principle for actual flight. Fascinated by gulls, Lilienthal designed a variety of gliders, which during the 1890's he launched from atop a man-made fifty foot hill near Berlin.[5] In concept, these machines were quite similar to today's sail planes and hang gliders. Much more so than modern gliders, Lilienthal's machines were subject to control problems and frequently crashed. Eventually he suffered a broken back in one of these crashes and died. However, he left careful studies for others to build on.

Among the most successful of those following in Lilienthal's footsteps were two American mechanics, Wilbur and Orville Wright. By observing birds, including turkey vultures, they were able to design their gliders with additional control features that made them much safer and more reliable. They were still gliders, though, dependant on being launched from a height into the wind in order to achieve flight. With no means of power of their own, they remained at the mercy of the winds.[6]

The idea of powering flying machines had been around for a long time as well. Even as the principles that allowed flight were being explored, ways to power that flight were being considered. All of these ideas came to naught for two reasons - weight and inefficiency. Many of these early engines were variations of the steam engine. A steam engine powering a locomotive or a loom can be made quite large to compensate for its inefficient performance. However, an aircraft must generate enough lift to raise itself and its cargo off the ground. The heavier the

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cargo (including the engine) the more energy is needed. Early steam engines were quite inefficient, in terms of power to weight ratios. What made powered flight a reality was the internal combustion, piston-powered reciprocating engine, first used to power automobiles. These engines were, for their time, remarkably powerful for a minimal weight. It was a modified automobile engine that would propel the Wrights to fame.[7]

For an aircraft to fly under its own power, a means must be found to translate the power of the engine into forward motion. In an automobile, the engine turns a crankshaft, which is connected via a transmission to the wheels. The transmission turns the wheels, which propel the car. A different application of the engine's power was needed for the airplane. That was found in the *propeller*. By the time of the Wright's flight, propellers had been used for over half a century to drive ships through the water, and the same principle could be adapted for flight. Mating the internal combustion piston engine with a propeller allowed the Wrights to achieve their historic powered flight in 1903.

Watching a piston-engined aircraft start its engine, taxi out and take off, one might expect that the rapidly spinning propeller is pulling the aircraft through the air. Although that assumption is true in some respects, the actual force which moves the plane is just the opposite. A propeller is an airfoil, just as the wing is. The flat(ter) surface is on the bottom, towards the aircraft, and the curved surface is on top, away from the aircraft. By causing the propeller to rotate, strong lift is generated on the bottom of the propeller. Thus, the spinning propeller, and the airplane it is attached to, is literally pushed through the air by the lift it generates.[8]

The mating of piston engine and propeller allowed man to achieve his age-long dream of powered flight, and it remains a viable means to power aircraft to this very day. There are,

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however, limits imposed by the laws of physics on the efficiency and power that it is possible to generate with this means of propulsion. While this is rarely an issue with private civilian aircraft, these limits would have a profound impact on the development of military aircraft, especially fighter aircraft, which require high speed and maneuverability.

There are several limitations on the ultimate power that can be generated for a fighter airplane with the piston engine and propeller combination. The first of these can be expressed in the form of power-to-weight ratio - that is, how much power is available per unit of weight of the power plant. For a piston engine, this is typically expressed in terms of horsepower per pound of engine weight. By the end of the Second World War, which represents the peak of the development of the piston engine as a power plant for high performance aircraft, the very best piston engines could generate approximately one horsepower for every pound of engine weight. To make any significant improvements in the engine's power required a significant increase in the weight of the engine, with attendant performance penalties.

The problem is more complex than a simple increase in weight. Another factor to be considered in the design of high performance aircraft is the resistance of the fluid through which it moves. For the purpose of flight this is known as wind resistance or *drag*. Drag is the primary force to be overcome to move the aircraft at high speeds. Drag increases as the speed of the aircraft does, but not in a simple linear relationship of say, one additional pound of drag for each additional mile per hour of speed. Instead, the drag forces increase by a factor equal to the *square* of the increase in speed. As an example, doubling an aircraft's speed (increasing by a factor of two) increases the drag by the square of that increase (in this case, four). So, a theoretical 100 pounds of drag at one hundred miles per hour becomes 400 pounds of drag at 200

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miles per hour. Double the speed again, to 400 miles per hour, and you increase the drag forces to 1,600 pounds. So as speed increases, the resistance of the air becomes increasingly powerful, requiring ever more engine power to overcome it.[9]

There are additional barriers in the way of the piston engine as a power plant for high performance aircraft. The propeller itself, the very thing which makes the piston engine useable as an aircraft engine, eventually inhibits the plane's performance. One way to achieve more power from a piston engine is to rotate the propeller more rapidly. Beyond a certain point, however, the efficiency of the propeller begins to diminish, and it provides less lift, not more. As anyone who has ever played a game of "Crack the Whip" can attest, the end of a rotating object moves at a much greater speed than the center. Eventually the increased rate of the propeller's rotation causes the tips of the propeller to approach the speed of sound. As this happens, turbulence is generated by the propeller, greatly diminishing its efficiency and its ability to move the aircraft more rapidly. Another limitation of the propeller is that at very high speeds, the wind resistance on the propeller itself acts as a brake, slowing down the entire aircraft.[10]

In addition to these problems, the reduced amount of oxygen at higher altitudes adversely affects the efficiency of piston engines. Below 10,000 feet, piston engines work as well as the design allows. As the operating altitude increases above this height, piston engines become increasingly inefficient. Above 20,000 feet, most piston engines have great difficulty functioning effectively. In order to function at these altitudes, a piston engine requires help to pressurize the air it needs for combustion. This is obtained by utilizing a supercharger, which compresses the air before it is fed into the engine for combustion. With superchargers, a piston engine can function up to about 40,000 feet, although its performance drops off fairly rapidly above 30,000 feet.

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All of these factors combine to produce a maximum level flight speed for a piston-engined combat aircraft of just about 500 miles per hour. Towards the end of the Second World War one German and two American fighters approached this speed. The German aircraft was the Dornier Do 335, a very unusual plane with one piston engine in the nose and a second engine in the rear powering a pusher propeller. The American planes were the North American P-51H, a special, lightweight, high-speed version of the standard P-51D Mustang, and the Republic XP-72, a proposed successor to Republic's earlier, highly successful P-47 Thunderbolt. The XP-72 had the largest piston engine ever put in a fighter aircraft, the Pratt & Whitney R-4360-13 Wasp Major engine, which developed 3,000 hp. The maximum speeds of these aircraft were: Do 335 - 474 mph, P-51H - 487 mph, XP-72 - 490 mph.[11] It was the urgent needs of the war, and the demands for constantly improving performance for fighter aircraft, that led to the implementation of a new and theoretically more powerful engine for fighter planes - the gas turbine, or jet, engine.

The basic principle of the gas turbine engine is quite simple - simpler in fact, than the piston engine. With a gas turbine engine, a flow of gas (or liquid) is passed over a wheel, called a turbine, which has angled blades attached to it. The flow of gas over these blades causes the wheel to turn. The wheel can be attached to other gears or machines and made to do work. Windmills and water wheels are basic gas turbine engines.[12] In its basic form, a gas turbine could not provide enough power to propel an aircraft, despite repeated efforts on the part of many inventors and engineers. Something else was needed to increase the energy output of the system.

That something was first conceived of by a British officer of the Royal Air Force, Frank Whittle. Whittle, a superb pilot and talented engineer, decided to try adding a compressor to the gas turbine engine.[13] His design was quite simple. Air entered the front of his engine, passed

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through the compressor, and was highly pressurized as it was passed into a series of combustion chambers. In these chambers, the high pressure air was mixed with a fine spray of fuel, creating a highly combustible mixture. This mixture was ignited, and the resultant extremely hot gas was ejected out the rear of the engine. As it exited the engine, this super-heated gas passed over a turbine, which was used to power the compressor. As long as there was fuel for the system, it could generate enormous amounts of energy.[14]

The actual propulsive force of a gas turbine engine derives from a simple principle of physics, know as Newton's Third Law of Motion - *For Every Action, There Is An Equal And Opposite Reaction*. As the flow of extremely hot, high pressure gas escapes from the back of the engine, it generates an equally powerful force pushing the engine forwards. When the engine is attached to an aircraft, this force allows the aircraft to fly at tremendous speeds.[15] Rockets, using the same action/reaction principle, have carried people into the vast reaches of space, at speeds far exceeding those attainable in Earth's atmosphere.

Whittle's original design, and its many subsequent variants, are known as *centrifugal flow* jet engines. This is due to the nature of the engine layout and air flow. In a centrifugal flow engine, the air flow curves around the central compressor, into a number of separate combustion chambers, and curves again into the exhaust chamber. Centrifugal flow engines are short and compact, but bulky. The other type of jet engine is the *axial flow* engine. An axial flow engine is relatively long and straight, allowing a more streamlined design. Primarily for this reason, most modern jet engines are axial flow. The primary way in which an axial flow engine differs from a centrifugal flow engine is the direction of the air flow. With an axial flow engine, the air enters the front and flows essentially straight through the engine. Instead of one large and bulky

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compressor in front, the air passes through a series of smaller, sequential compressors. Each compresses the air a bit more than the one in front of it. The single combustion chamber is directly behind the compressors, and the exhaust chamber behind that. The axial flow engine is so efficient that usually a substantial flow of uncompressed air is diverted around the outside of the main chamber, primarily to cool the combustion and exhaust chambers.

Jet engines, whether centrifugal or axial flow, have a number of inherent advantages over the piston engine as an aircraft power plant. The first of these is perhaps the most obvious - the lack of a propeller. Propellers, as discussed above, are actually barriers to high speed flight. By dispensing with the propeller, jet powered aircraft avoid the difficulties of drag on the propeller and turbulence caused by propeller tip speed.

Another problem with piston-engined aircraft is that the efficiency of their engines decrease with the increase of altitude. At higher altitudes, the atmosphere contains less oxygen, making it more difficult for the engine to burn its fuel. Above a certain altitude (about 20,000 feet for ordinary engines, and about 45,000 feet for supercharged engines) piston engines cannot function effectively enough to maintain the aircraft's flight. Jet engines, on the other hand, actually *increase* in efficiency as the altitude increases. This is due to the greatly decreased air pressure at higher altitudes. This decreased air pressure allows the exhaust flow of the jet engine to move even faster, generating even more thrust for the aircraft.

The third, and perhaps most important advantage jet engines have over piston engines is in the area of power-to-weight ratios. As was discussed above, beyond a certain point, to increase the power output of a piston engine requires a substantial increase in the engine's weight. Jet engines, because they derive their propulsive force from the exhaust gases and not the explosive

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combustion of piston engines, can increase their power substantially for only minimal increases in weight. Today's lightweight and high temperature alloys allow jet engines to produce power, or *thrust*, (measured in pounds), in amounts unthinkable for piston-engined planes. Modern jet fighter engines are capable of producing more thrust than the aircraft weighs, allowing them to actually climb vertically like a rocket, a feat no piston engined plane could even come close to duplicating. This increased power also allows for ever-greater speeds.

The early jet engines, such as those powering the planes that are the subject of this study, did have some disadvantages relative to piston engines. One of the most significant was in terms of fuel consumption. While at high speeds early jet engines were relatively fuel efficient, at low speeds and low altitudes they were much less efficient. Even at their most efficient, they burned fuel in prodigious quantities. This sharply limited both their operational range and their time in the air. Both of these limitations are important to fighter planes.

The other primary limitation of the early jet engines was their vulnerability to damage. Piston engines, especially the big and rugged radial engines, could absorb enormous amounts of damage and still continue to operate. The Second World War produced many stories of radial engined planes losing one or more engine cylinders to battle damage, yet continuing to operate flawlessly. Barring damage to the oil cooling system, or with the liquid cooled in-line engines, the coolant system, piston engines were hard to wreck in combat. The early jet engines, in contrast, were rather temperamental and fragile, and easily damaged. Damage to any of the major systems - the compressors, the combustion chamber or the turbine - could put the whole engine out of operation very quickly. And because the engines relied on a constant flow of air through the engine, they were quite vulnerable to ingesting foreign matter - ice, rocks, birds, bullets, or

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whatever.

These limitations on the engines would have an effect on the roles that jet fighters could perform well. They turned out to be excellent at the traditional air superiority tasks - combating enemy fighters and trying to shoot down enemy bombers. They were less successful, especially in comparison to the older piston engined fighters, at some other missions, such as air-to-ground interdiction and low-level tactical bombing. This situation will be discussed in greater detail in the sections on the combat use of the early American jets in Korea.

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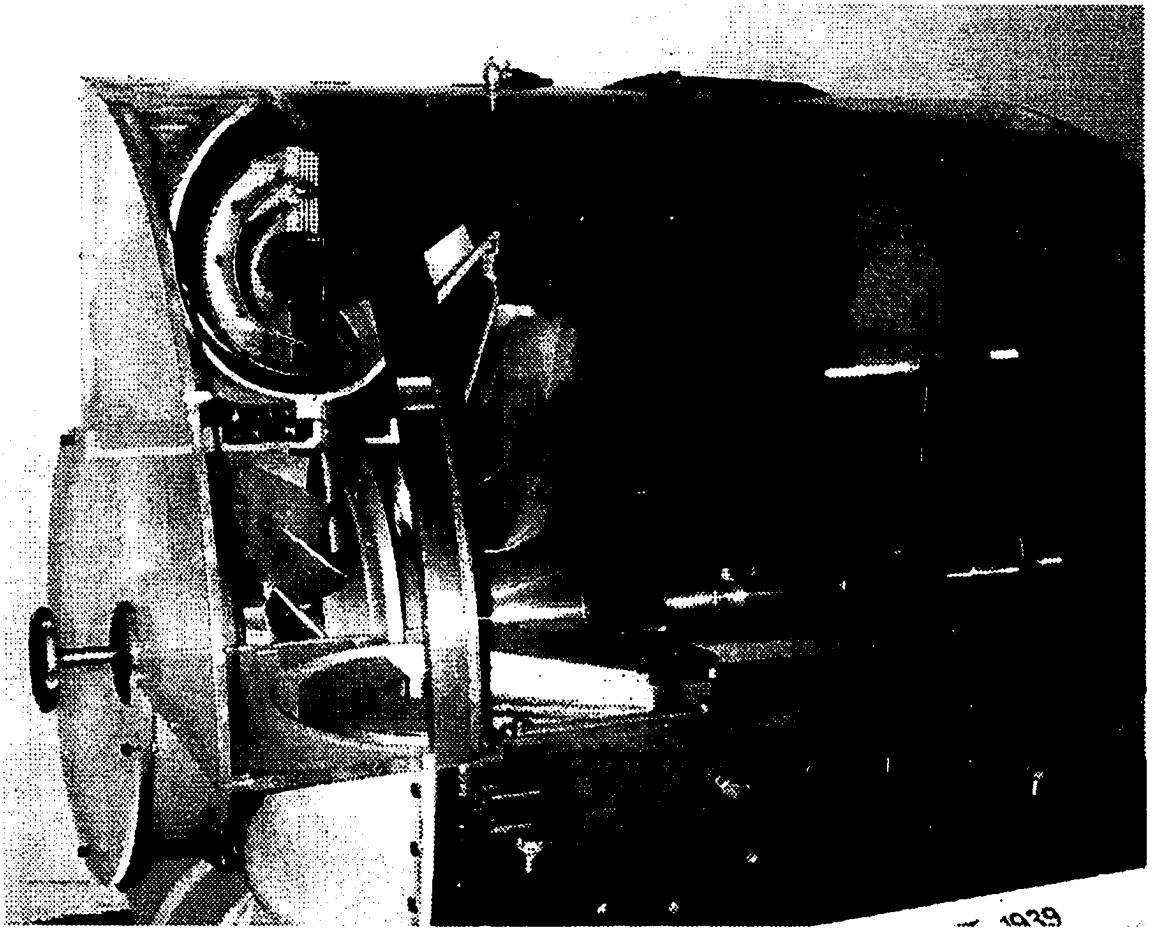
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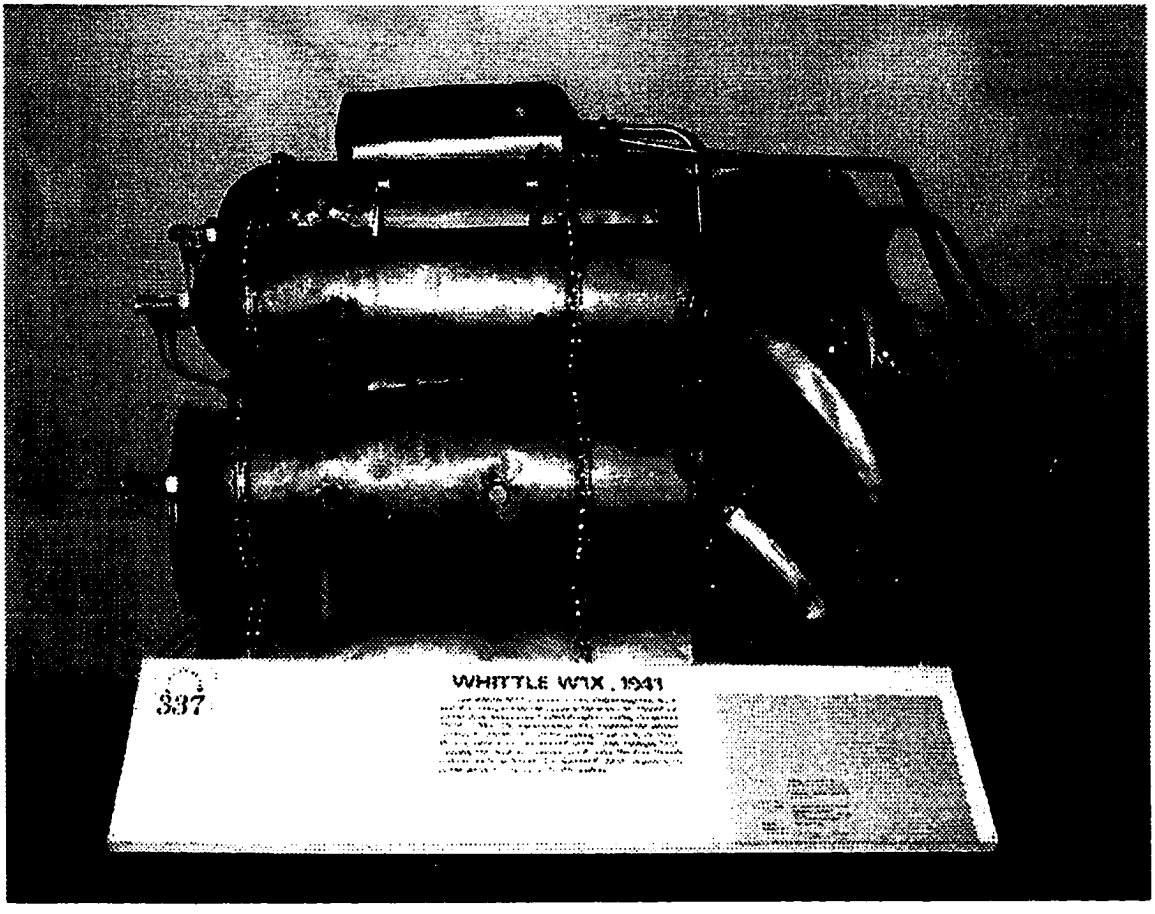
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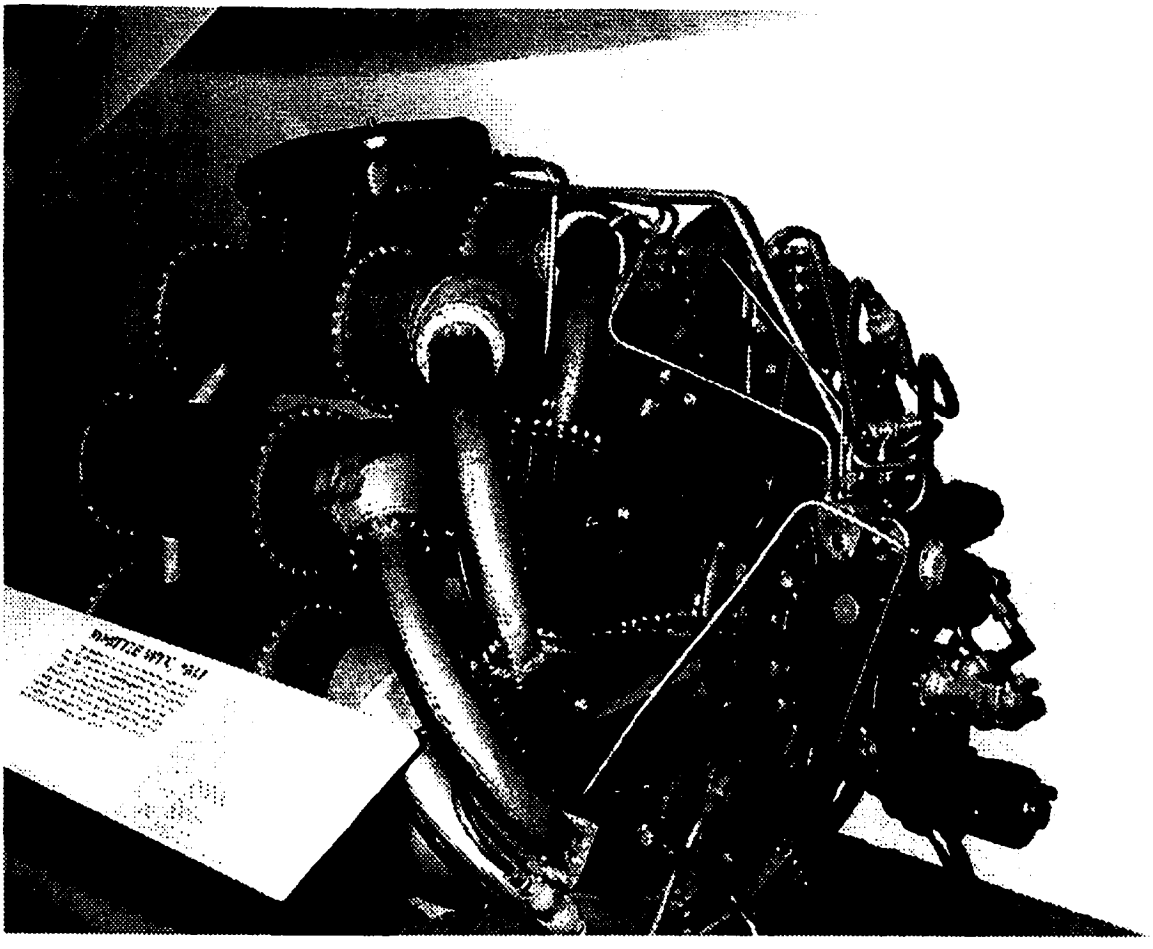
Cutaway exhibit of the German Heinkel He S3B centrifugal flow jet engine. This engine was used to power the Heinkel He 178, the world's first jet powered aircraft. Note that the S3 uses a small axial compressor just forward of the larger centrifugal compressor. This engine is on display at the National Air and Space Museum of the Smithsonian Institution. (Author's photo)

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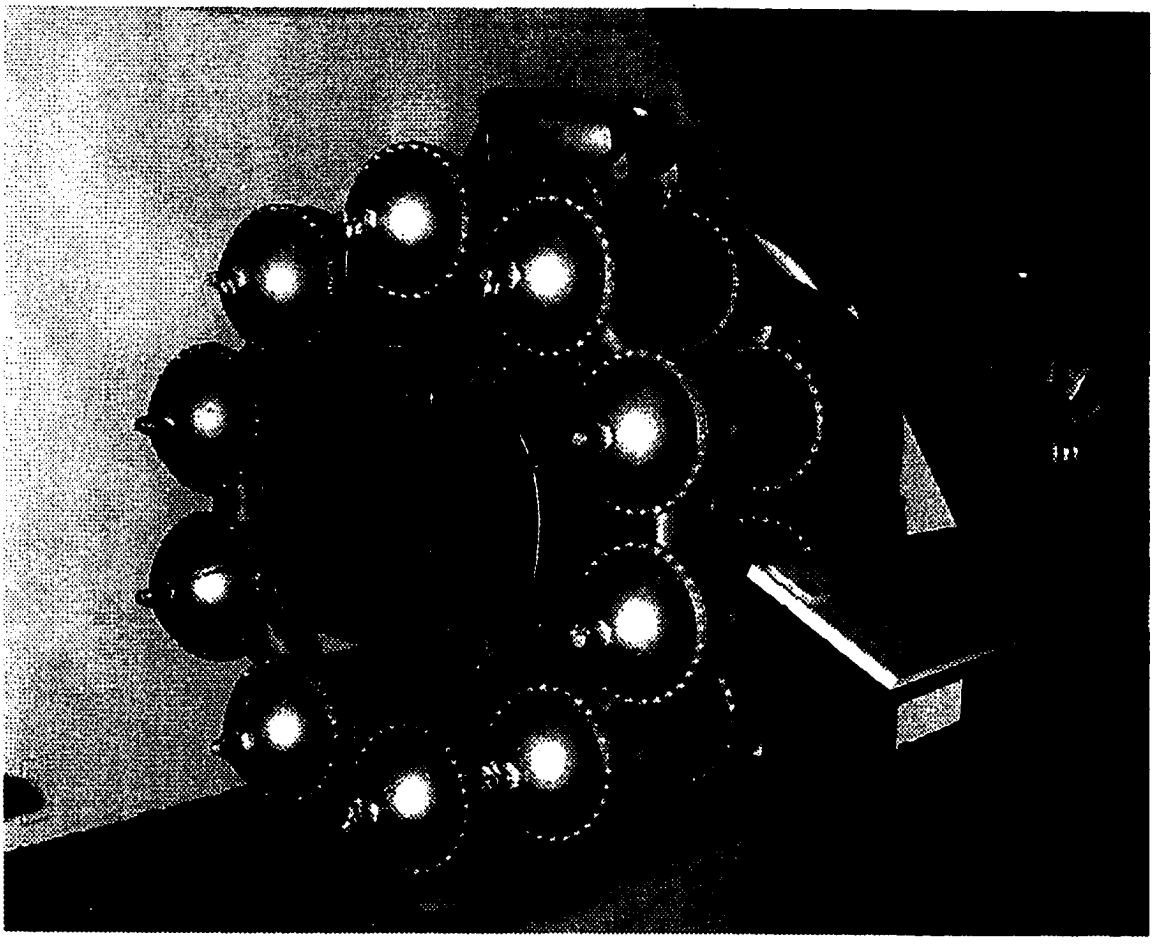
The Whittle W.1X jet engine, the first engine to power the Gloster E.28/39 Pioneer experimental jet aircraft. The large compressor is to the right, and the various combustion chambers each connect to the airflow from it. This engine is also on display at the National Air and Space Museum of the Smithsonian Institution. (Author's photo)

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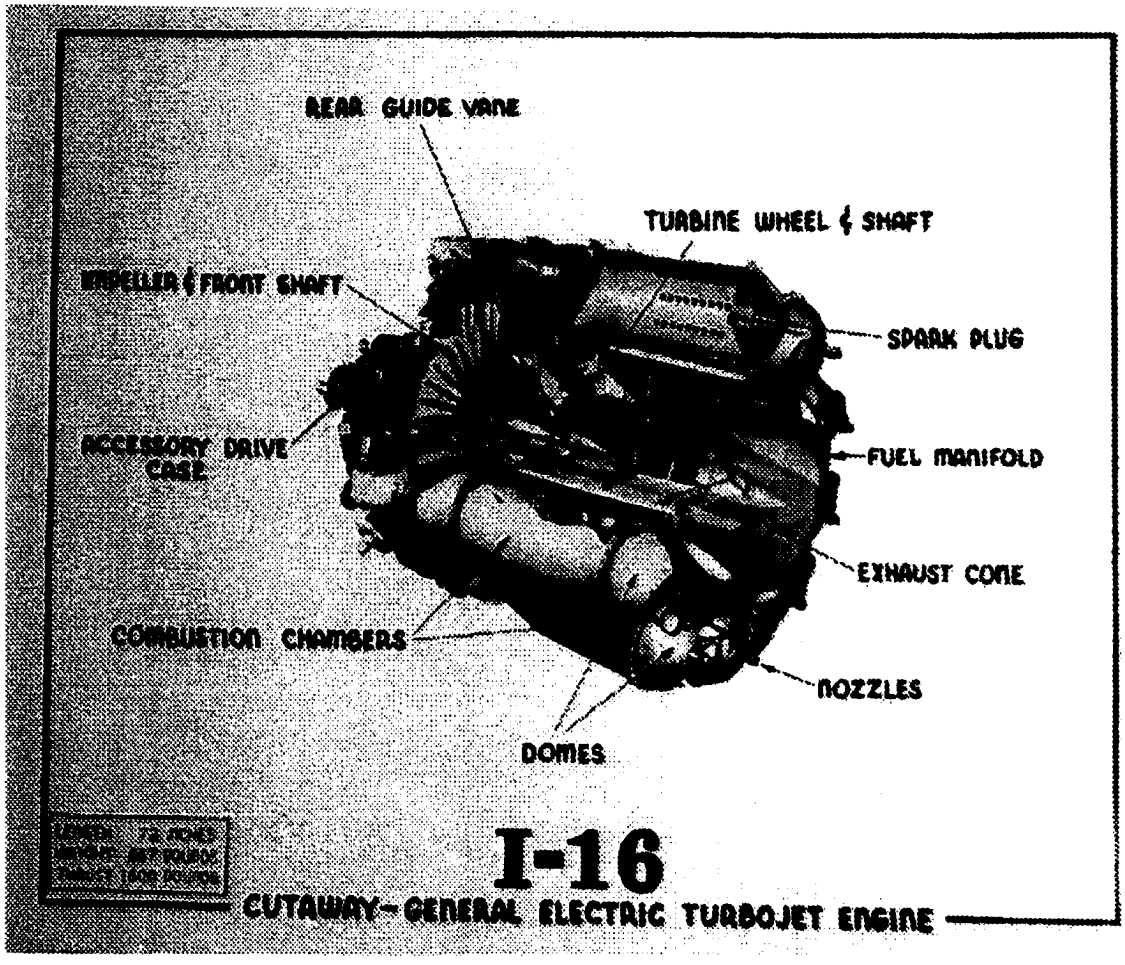
View of the W.1X engine from the front, looking at the compressor housing. (Author's photo)

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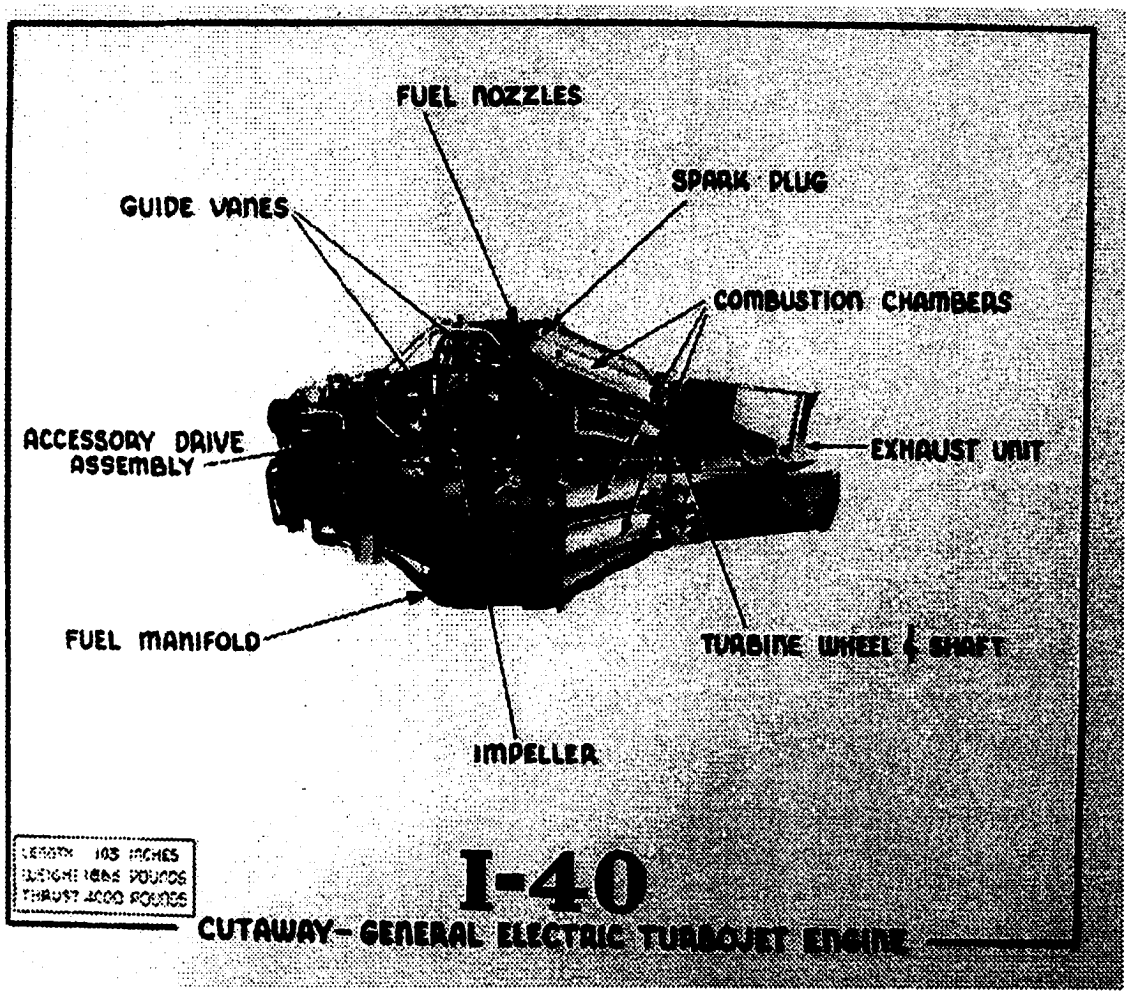
The W.1X engine from the rear, showing the circle of combustion chambers and the exhaust gas outflow port. (Author's photo)

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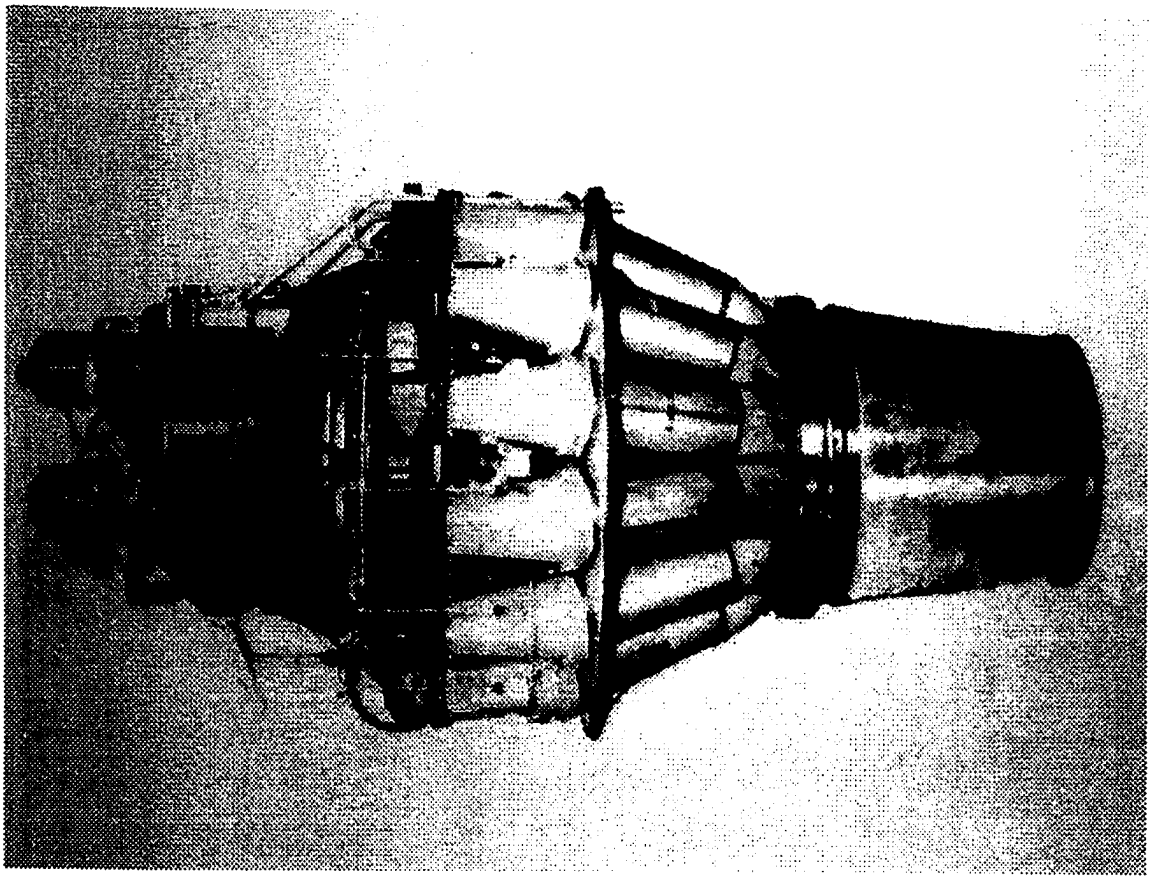
A cutaway drawing of a General Electric I-16 centrifugal flow jet engine. Note that the exhaust outlet is actually inside the ring of combustion chambers, rather than behind them, as it would be on later engines. This type of engine would be used to power the Bell P-59 Airacomet. Photo courtesy of General Electric.

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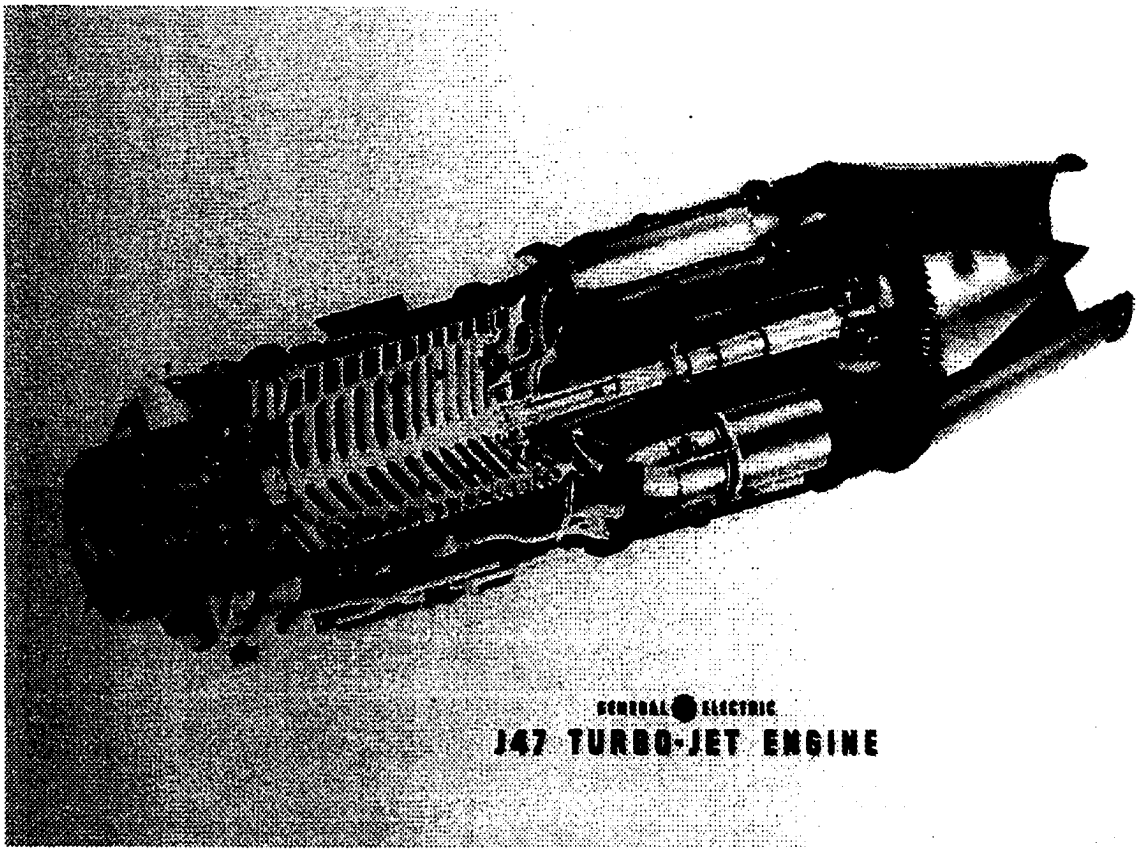
Cutaway view of a GE I-40 (known to the Air Force as the J33) centrifugal flow jet engine. This engine would be the power plant for the Lockheed P-80 Shooting Star. Photo courtesy of General Electric.

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Photograph of a General Electric I-40/J33 engine. The compressor is to the left in the picture, with the ring of combustion chambers in the center, and the exhaust outlet on the right. Photo courtesy of General Electric.

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A cutaway view of a General Electric TG-190/J47 axial flow engine. The series of small compressors can be seen to the left of the combustion chambers. Just in front of the exhaust cone is the turbine wheel. This engine was used to power the North American F-86 Sabre. Photo courtesy of General Electric.

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"It was as though angels were pushing."
General der Flieger Adolph Galland, describing his first flight in a Me 262[1]

Chapter 2
Foreign Innovations

As mentioned previously, the first practical design for a gas turbine engine came from an unlikely source - a serving officer in the Royal Air Force, Flying Officer Frank Whittle. At first glance an unlikely candidate for a designer of this revolutionary power plant, Frank Whittle in fact had excellent qualifications for the undertaking. In addition to being a superb test pilot and flight instructor, Whittle also had a naturally inquisitive mind and had received a first-class engineering education at Cambridge University as part of his military career.[2]

Whittle was by no means the first person to attempt to produce a gas jet power plant. Many others had attempted this, but the resultant designs were either too complex, going beyond the existing state of technology, or else they had design flaws resulting from the designer's lack of engineering knowledge.[3] Whittle's centrifugal flow engine design had one of the characteristics of true inventive genius - simplicity. Whittle was able to take a new and complex idea and find a way to utilize it in simple, practical terms. Whittle's design was so simple, in fact, that it was dismissed out of hand by most of the engineering experts in the British aviation industry. Dr. A. Griffith, a British mathematician and aerodyanmicist who had designed a complex, innovative, futuristic and completely impractical gas turbine engine, was asked to comment on the young officer's design. Displaying the arrogance, ego, and disdain that would typify much of the British aviation industry's attitude towards Frank Whittle and his invention for many years, Griffith simply rejected Whittle's calculations and work. He offered no empirical evidence for this

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rejection, which was apparently based entirely on the fact that Whittle's figures and data differed from his own.[4]

Whittle patented his engine in 1930 and then attempted to interest various British companies in his design. The response was uniformly negative. Germany's jet pioneer, Hans Pabst von Ohain, later stated that, in his opinion, had England funded and supported Whittle's work at that time, World War II might not have occurred, as England would have had an almost insurmountable lead in jet engines and aircraft.[5] Instead, Whittle continued to fly for the RAF and advance his engineering education at Cambridge. His patent on the jet engine came up for renewal in 1935, but the five pound fee was too much for Whittle's budget, and the patent was allowed to lapse.[6] Eventually, in 1936, Whittle was able to secure financial backing and formed a small company, Power Jets Ltd., to test and develop that gas turbine engine.[7]

Operating on a shoestring budget in an abandoned factory, Whittle was able to construct a crude static prototype engine, to test the theory of jet propulsion. The engine worked, indeed almost too well, at times nearly incinerating members of the staff. There were a number of problems resulting from the crude construction, including several instances of runaway engine speed, which were potentially quite dangerous, but no serious damage to the engine or bystanders actually occurred. Enough data was gathered from the tests to show that this type of engine had enormous potential as a power plant for aircraft. As Whittle and his small team struggled with their innovative work, they were caught up in the momentous events that were convulsing Europe and the world. As the Second World War erupted, Whittle's work became more important than ever. Paradoxically, the war also had the frustrating effect of preventing the government from investing serious time and money in his work. The needs of the moment -- the defense against

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Nazi Germany, with existing technology -- took precedence.

Nazi Germany, indeed, was the one other country where serious work was being done on the gas turbine engine. The German efforts began later than Whittle's, but had a number of important advantages. Whittle was, simultaneously, an officer of the Royal Air Force, an engineer and inventor, and one of the heads of the small, independent company he had founded to research and produce his engines. The combined stress of these responsibilities would eventually hospitalize Whittle late in the war. By contrast, the German efforts were being undertaken by established scientists and engineers at large and successful aircraft and engine companies. The man who would become known as the father of the German jet engine was Hans Pabst von Ohain, who worked for Heinkel, a major aircraft company. In Nazi Germany, military aviation was a high priority, and the various aircraft companies were strongly supported and subsidized by the government, and allowed to pursue much independent research. As a result, despite starting his work a number of years later than Whittle, Ohain was the first to actually produce a jet-powered airplane.

Whittle's design had been patented in 1930, but there is no evidence that Ohain's work was derived from Whittle's. Ohain stated that he had not seen Whittle's work, although the other engineer on the early project, Wilhelm Gundermann, asserted that the team kept abreast of foreign work.[8] Although Ohain's original design was, like Whittle's, a centrifugal flow engine, it had marked differences from the Englishman's. Ohain's original engine, the S2, was a centrifugal flow design somewhat similar to Whittle's, but with the addition of an axial compressor before the centrifugal compressor.[9] German jet engine design thereafter took a different approach, and concentrated on axial flow engines. Ohain's work was imitated at three other aviation firms,

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BMW and Bramo, which made aircraft engines, and Junkers, which produced both engines and aircraft. Unlike Whittle's repeated attempts to involve the British government, the various German efforts were private corporate ventures, although the government did follow the development progress of these new engines. Heinkel, for instance, did not inform the German government of their attempt to use this new power plant in an aircraft, treating it as an in-house research project. The project reached fruition in August of 1939. Just days before the Wermacht blitzkrieg was unleashed on Poland, the world's first jet powered aircraft took to the air. This was the Heinkel He 178, and its flights were simple and slow. In appearance a hollow tube with short wings, a tail, and a cockpit, the He 178 had only one purpose - to prove the viability of the jet engine as an aircraft power plant. This it did successfully, and set the stage for the most innovative and successful jet aircraft programs of the war.[10]

In England, Whittle continued to struggle to develop his engine. Although the war gave his project a somewhat higher priority, he continued to face skepticism, derision and obstructionism. Power Jets was essentially a design firm, lacking the facilities, equipment and personnel to actually mass produce the engines. Power Jets therefore was affiliated with several other companies in an effort to produce the engines. Power Jets would design, and the other companies would build the engines. Unfortunately for Whittle and Power Jets, these early associations proved more a hindrance than a help.

The first firm associated with Power Jets was British Thompson-Houston. BTH was a manufacturer of power turbines. This well-established firm was supposed to lend its production expertise to Whittle's inventiveness. Unfortunately, BTH was a producer of immense and massive turbines for power plants. They were not equipped by training or experience for working

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with small, light, high temperature turbines. Their senior engineers were not familiar with or experienced in the needs of aviation, and displayed no real inclination to learn[11]. As Whittle remarked about his association with BTH, "It was a bit like expecting the makers of Big Ben to make a good job of a lady's wrist-watch."[12] BTH proved to be of limited usefulness to Whittle and Power Jets.

The other firm involved in early development work with Power Jets could not even be said to have been of limited usefulness. The Rover Car Company was brought in because of their experience with engine manufacture. This proved to be an unfortunate choice, as Rover was more interested in advancing their fortunes at the expense of Power Jets' than in actually developing the jet engine. Rover essentially tried to steal Whittle's designs and work, and shut him out of the field of jet engines.

> The engine itself appeared a nice simple piece of engineering - so simple that even a young RAF Squadron Leader had been able to design it! Seemingly, if they played their cards right, there was little to prevent them taking over the whole job completely. The Ministry would be the main customer, and so any Power Jets patents, valid or otherwise, would be no obstacle.[13]

Whittle later estimated that as much as two years of development time were wasted by the sloth, negligence and back-stabbing of Rover.

British foot dragging was not limited to private industry, however. The government and the Royal Air Force managed to get in on the act as well. Many leading scientists remained convinced that the gas turbine engine was a waste of time and a dead end, and had no hesitation in expressing that opinion. John Golley's book on Frank Whittle reproduces in one of its photographic sections a portion of the conclusion of a British government report. The section

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reads as follows:

> In its present state, and even considering the improvements possible when adopting the higher temperatures proposed for the immediate future, the gas turbine engine could hardly be considered a feasible application to airplanes mainly because of the difficulty in complying with the stringent weight requirements imposed by aeronautics.
> The present internal combustion engine equipment used in airplanes weighs about 1.1 pounds per horsepower, and to approach such a figure with a gas turbine seems beyond the realm of possibility with existing materials.
>
> The Committee on Gas Turbines
> appointed by
> The National Academy of Sciences
> June 10, 1940[14]

Although a few government officials believed in Whittle's work and attempted to help him, it was a difficult, uphill battle. A plane was proposed to test Whittle's engine, the Gloster E.28/39. British aircraft designation numbers are intended to indicate both the type of aircraft and the year it was initiated. Hence, Experimental Number 28/ 1939. Even though initiated in 1939, it did not fly until May of 1941, largely as a result of obstructionism by Rover, the government, and others. There was nothing unique about the aircraft itself. It was, like the He 178, merely a test-bed to determine the viability of the jet engine. Unlike the Heinkel design, the E.28, which was never formally named but was often referred to as the Pioneer or the Whittle, proved to be an adaptable design, and continued to test the various improved versions of the Whittle engines.

With the conclusion of the Battle of Britain in late 1940, and the retreat of the specter of invasion by the Wehrmacht, the British government began to take a longer view of the war, and was more receptive to advanced ideas like Whittle's. This led to a proposal for a fighter airplane powered by Whittle engines, designated the F.9/40 (Fighter Number 9, 1940). This aircraft would

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eventually become the Gloster Meteor, the only jet aircraft produced by the Allies during the Second World War to see actual combat. It is interesting to note that the proposal for this aircraft was accepted well before the E.28 actually flew, so the various government and Air Force officials involved were sufficiently convinced of the jet engine's potential to commission a fighter airplane using it as a power plant, even before any actual tests of jet powered aircraft were conducted.[15]

Whittle continued to have difficulty with the various companies that worked with him. Eventually, at the beginning of 1943, the Rolls Royce company was brought into the picture. Collaboration between Power Jets and Rolls Royce had been proposed before, but nothing had come of it. This was unfortunate for both Whittle and England's jet program, as Rolls Royce was probably the best choice of a firm to be involved in the design and manufacture of jet engines. Rolls Royce was the designer and builder of the magnificent Merlin engine, which was the power plant for such excellent aircraft as the Spitfire, Hurricane, Lancaster, Mosquito and Mustang. Within months of Rolls Royce being brought into the business, the development and testing of the jet engines was drastically accelerated. Eventually Rolls Royce would produce a series of excellent jet engines, becoming one of the world's leaders in this new industry.

Whittle realized that by becoming involved with Rolls Royce, he could eventually lose control of his creation, the jet engine. What he did not expect was the means by which he would lose that control. Whittle wrote to Sir Stafford Cripps, the Minister of Aircraft Production, in April 1943, to suggest a way to rationalize jet engine design and production. What he suggested was that the government nationalize all jet engine companies, and administer the program directly. This would prevent various private companies from stealing Whittle's work, and leave him in

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control of the design and development, even if he could no longer control production. Sir Stafford took Whittle's suggestion in an interesting direction, and chose to nationalize only Power Jets, offering to buy them out for a ridiculously low sum or have the government simply close them down. This was not at all what Whittle had envisioned, and it gave Rolls Royce a clear field for jet engine design and manufacture.[16]

The E.28 Pioneer, with progressively more powerful engines, was flown before various senior government officials. In April 1942 it was flown for Prime Minister Winston Churchill. As these demonstrations included low-altitude, high-speed passes over the airfield at speeds beyond that of any piston engined fighter, the officials were duly impressed. Churchill demanded to know why squadrons of jet fighters were not already available, and a much higher priority was given to the whole program.[17] In addition to the Gloster F.9 Meteor, the de Haviland aircraft company was developing their own jet fighter. Known as the Vampire, it would come too late to see service in the war, but, along with the Meteor, would become a major component of Britain's post-war air force.

The Pioneer was a short, rather tubby aircraft, to accomodate the squat and bulky shape of Whittle's centrifugal flow engines. It had a tubular fuselage, with mid-mounted wings and a high tail structure. Unusually for a British aircraft, it also had tricycle landing gear, with two main wheels and a nose wheel rather than the traditional tail wheel, necessitated by the power and temperature of the jet engine's exhaust.

Interestingly, some of the early German work with jet aircraft did not realize the need for this arrangement of the landing gear, and at least one early German jet, the Me 262, was originally designed in the conventional tail-down attitude of most fighter aircraft. The tail-down attitude of

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the Me 262 had several serious side effects. The wings blocked the flow of air over the tail surfaces, which prevented the plane from "unsticking," or leaving the runway. A temporary (and very dangerous) solution to this problem was to have the pilot tap the brakes once the plane reached take-off speed, thus bringing the tail up and allowing the aircraft to take off. Also, the hot jet exhaust from its twin engines repeatedly set fire to grass and even blacktop runways. For both of these reasons, the Me 262 was quickly given tricycle landing gear.[18]

The E.28's single large air intake was located in the nose of the plane, and the engine mounted in the center, just aft of the pilot. Performance at first was adequate, proving the viability of the jet engine, but until larger, more powerful engines became available, it was inferior in performance to the latest piston-engined fighters. The Pioneer also did not have the various items that a normal fighter would, such as armor plate, self-sealing fuel tanks, guns, and ammunition, all of which add considerably to a combat aircraft's overall weight. The lack of these items and the resultant saving of weight added considerably to the Pioneer's performance.

The Gloster Meteor, England's first jet fighter, was a longer, leaner design. The pilot sat near the front of the oval-sectioned fuselage, with a bubble canopy. The wings were well forward, mounted in the middle of the fuselage, and the tail surfaces were raised quite high. It was a twin engined design, with the engines mounted in pods on the wings. The engine pods were mounted with the wings bisecting them, so they protruded both above and below the wings. The pods bulged forward, and narrowed aft, again because of the compact, squat design of the engines. Like the Pioneer, the Meteor also used tricycle landing gear. Performance of the Meteor exceeded that of piston engined fighter planes, but not by large margins. It was a capable design, but with little room for significant improvement and modification.[19]

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The de Haviland Vampire was the most unusual looking of these early British jet aircraft. The engine was mounted in the compact fuselage, with twin air intakes on the sides of the fuselage and a single exit in the rear. The wings were mid-mounted, but the most unusual feature was the tail. The tail surfaces were mounted on a thin pair of booms which extended back from the wing. As the fuselage ended at the rear of the wing, this gave the Vampire a boxy shape. Unlike the Meteor, the Vampire was not completed in time to see service during the war. The Vampire's performance was roughly equivalent to that of the Meteor, and like the Meteor, it would serve in the British and other air forces for many years following the end of the war.[20]

As stated previously, of the British jets only the Meteor participated in combat operations during the war. Much of the Meteor's aerial combat was limited to attempting to intercept and destroy the pilotless V-1 cruise missiles the Germans were launching at London. Although not enormously faster than conventional piston-engined aircraft, the Meteor did have a small but crucial speed advantage at low altitudes. The extra twenty-five mph that the Meteor was capable of at the altitudes at which the V-1 flew often made the difference between success and failure in intercepting the missiles. All Meteors therefore remained based in England until the menace of the V-1 abated.[21]

Eventually the Allies overran the Dutch launching sites of the V-1, and in early 1945 Meteors were transferred to the continent for more conventional air operations. At first the paranoia of national security restricted the Meteors to operating only over Allied territory. This was overly cautious, as the Germans had been operating jet combat aircraft for almost a year by that time, and the limitations were eventually lifted. By the time Meteors were cleared to operate over enemy territory, German resistance, both on land and in the air, was collapsing.

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Consequently, although Meteors attacked several German airfields, and claimed a number of German aircraft destroyed on the ground, they did not engage any German aircraft in combat. Thus, the combat missions of the only operational Allied jet plane were limited to chasing and shooting down cruise missiles, patrolling over their own territory, conducting occasional photo reconnaissance missions, and strafing targets on the ground.[22] Fortunately for the Allies, they did not need the new jet aircraft to win the war, and were able to manage quite well with conventional piston-engined planes. The story of the German jets is more complex, and these planes had the potential for a much greater impact on the outcome of the war.

Despite starting later than the British with jet engine technology, both the German aviation industry and the German government were more receptive to the innovative concept, and consequently a great many jet aircraft of various types were produced in Germany during the Second World War. Indeed, during the war the German aviation industry produced more jet aircraft, and jet designs, than any of the other powers. Many of the concepts pioneered by these designers would influence the aviation industry for decades to come, and deserve examination.

Germany produced five jet aircraft that entered combat operations during the war. These aircraft were the Messerschmitt Me 262 *Schwalbe* or *Sturmvogel* (Swallow or Stormbird), the Arado Ar 234 *Blitz* (Lightning), the Heinkel He 162 *Volksjaeger* (People's Fighter), the Messerschmitt Me 163 *Komet* (Comet), and the Bachem Ba 349 *Natter* (Adder). In addition to these combat aircraft, a number of jet aircraft designs had one or more prototype aircraft constructed. Some of these prototypes were flight tested, while others were overtaken by the chaos at the end of the war and never recorded any test flights, although some of them, acquired by the Soviets, may have been tested in the Soviet Union. These prototypes include the Horten

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Ho IX/Gotha Go 229 flying wing, the Messerschmitt Me 263 rocket fighter, the Junkers Ju 287 heavy bomber, the Henschel Hs 132 jet dive bomber, the Heinkel He 280 fighter, and the Messerschmitt P.1101 fighter. One further addition to this roster should be the Focke Wulf Ta 183, a jet fighter that was ordered into production in the waning days of the war, but was never completed, as the factories producing its components were overrun by the advancing Soviet forces. To this impressive list could also be added dozens of proposed aircraft from the final 6 months of the war, some of which were merely a few sketches on paper, while others were fairly complete engineering designs. These proposals include such unusual designs as pulse jet and ram jet powered aircraft, sleek giant bombers, flying wings and wedges, and other designs that would not look out of place on military airfields today.[23]

By far the most important and numerous of all of these jets was the Me 262. Its advanced design, high performance and powerful armament produced considerable trepidation among Allied senior commanders. Many people, both at that time and since, have argued that if the Me 262 had been available in quantity earlier, it would have altered the course of the war. The blame for the delay in the Me 262's production is often assigned to Hitler, the result of an order he issued to the effect that the Me 262 be built as a bomber. The real story of this fascinating aircraft is more complex, and perhaps not as earth-shattering as many people believe. It is nonetheless a pivotal aircraft, both in the innovations pioneered in its design, and the impact it would have on future aircraft designs.

The Me 262 had its origins in a design proposal from *Technische Amt*, the Technical Department, of the *Reichs Luft Ministrie (RLM)*, the German Air Ministry. This proposal called for a fighter aircraft utilizing as powerplants two of the new "Special Power Plants" as the axial

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flow gas turbines that were under development at BMW were known. Both Heinkel and Messerschmitt produced designs for this contract, and both planes were built and tested. The Heinkel design, the He 280, was not built beyond the few prototypes. The Messerschmitt design, the Me 262, won the competition and began its development. Initial estimates both of the availability and the power of these new engines were hopelessly optimistic and resulted in major modifications to the design. Originally the engines were to be located inside the aircraft's fuselage in the wing roots, but as the engines were considerably larger than planned, they were relocated to pods, or nacelles, hung under the wings.[24]

As the original BMW engine, designated the 003, proved to be both underpowered and unreliable, the decision was made to use instead an engine developed by another firm, Junkers. This engine, the Jumo 004, would power both the Me 262 and the Ar 234. The BMW engine was eventually improved enough to power the He 162 fighter. The initial design of the Me 262 showed a great deal of promise, but as Germany seemed to be winning the war at this time (early 1942), no great urgency was attached to the project.

One feature of the design, which would have a great impact on the performance of the Me 262, was the decision to sweep back the wings. Until this time, virtually all aircraft wings stuck straight out from the fuselage. Occasionally, the leading edge would be angled back slightly, but this was usually done with low performance planes such as the Douglas DC 3 transport and the Heinkel He 111 bomber. With the Me 262, for the first time, a high performance fighter plane would have this characteristic. Due to the nature of high-speed flight, angling the wings back allows the aircraft to fly at faster speeds with the same power plant than would be possible with straight wings. For very high speed flight, especially at speeds near or exceeding the sound

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barrier, swept wings are essential, to prevent the wings from being caught in and damaged by the shock wave created by the high speed air flow. Although this effect had been theorized, prior to the Me 262 there was no swept-winged aircraft fast enough to test this theory. The decision by the Messerschmitt design engineers to angle the wings of the Me 262 was a deliberate attempt to improve the performance of the aircraft, but when it was made there was no empirical evidence to back up the idea. With the new swept wing design, Messerschmitt managed to accomplish something unusual in aircraft design - getting an untested new design feature almost exactly right the first time.[25] This new swept wing explains why the Me 262 was approximately 50 mph faster than the Gloster Meteor, despite the two aircraft having essentially the same amount of power available from their engines.[26]

Despite the advocacy of such important figures as *Generalleutnant* Adolph Galland, who oversaw all fighter design, production and deployment in the *Luftwaffe*, the Me 262 project languished, in part because Prof. Willi Messerschmitt, the head of Messerschmitt AG, as well as its chief designer, was not very interested in the project, preferring to work on one of his own projects, the Me 209, a derivation of his famous Bf 109 design of the late 1930s. Even after the Me 262 was officially ordered into accelerated development, Messerschmitt continued to favor his Me 209, even after the RLM officially canceled the project.

Although the Me 262 first flew with jet engines in July of 1942, only a handful of pre-production models were ordered by the *Luftwaffe*. As late as the spring of 1943 the Me 209 was still favored over the Me 262. But by the end of May, 1943, the Me 209 was dropped from production and the Me 262 was to be placed in accelerated development. Prof. Messerschmitt, who was very committed to the Me 209, pulled strings and managed to keep the Me 209 under

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development until November 1943, when it was officially and permanently canceled, and he was ordered to focus on the Me 262.[27]

Not all of the blame can be directed at Prof. Messerschmitt, though. Technical difficulties, which would dog the Me 262 throughout its career, consistently delayed the project. Technical problems are attendant with any new aircraft, especially one which utilized several new features, as did the Me 262. Most of these problems were eventually worked out, but one serious problem continued to plague the program -- the engines.

Gas turbine engines operate at much higher temperatures than conventional internal combustion piston engines. These higher temperatures require that large portions of the engine, especially the combustion chamber, turbine mechanism and exhaust chamber, be manufactured from high-temperature steel alloys, as ordinary steel and aluminum are incapable of resisting such extreme temperatures. Nickel and chromium were the two metals needed to manufacture these alloys, and neither was available in quantity to German industry. As a result, German industry was forced to utilize a number of poor substitutes for these alloys. The combustion chamber of the Jumo 004 engine, for example, was produced from ordinary steel which had an aluminum coating baked on in ovens.[28] This expedient resulted in poor performance, engine fires, and early engine loss. Likewise, the turbine blades and exhaust housing, manufactured from ordinary steel, suffered from "creep," a systematic distortion of the metal caused by the high temperatures. This likewise affected engine performance adversely, often to the point of engines quitting while in flight.

These basic metallurgical problems were never fully overcome by German industry, as the problem was the availability of raw materials, not the design of the engine. As a result, the early

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Jumo 004 engines lasted for only about ten hours of operation before they required complete replacement. By refining the engineering process, the useful life of the engines was eventually raised to twenty-five hours. At that point the engine design was "frozen" and no more modifications were attempted, so that the engine could be placed in mass production. The decision to freeze the design and begin mass production of the Jumo 004 was not made until September, 1944, which meant that the Me 262 was not available in quantity until early 1945, too late to significantly affect the outcome of the war.

A twenty-five hour useful life means that after twenty-five hours of operation, half of the engines will have seriously malfunctioned and need to be replaced. By way of comparison, piston aircraft engines last hundreds of hours, tank engines thousands of hours, and diesel truck engines can last hundreds of thousands of hours before needing to be replaced. Although the Me 262 was not the only early jet to suffer from short engine life, it was perhaps the most significantly impacted. The drastically short engine life of the Jumo 004 had serious adverse affects on the combat readiness of the Me 262. At any given time at least half, often two-thirds of all the Me 262s in a unit were having one or both of their engines replaced and were therefore unavailable for combat operations.

These difficulties with the engines have a direct bearing on the major controversy surrounding the Me 262. The capabilities and potential of the Me 262 had badly frightened many Allied commanders, and they were grateful that the aircraft appeared only in small numbers late in the war. The fact that the aircraft was designed in 1940, and was flying on jet engines in mid 1942 has prompted many people to speculate that some sort of ineptitude was responsible for delaying its introduction into combat. A frequently cited source of that ineptitude is an order issued by

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Adolph Hitler that all Me 262's be produced with the capacity to carry bombs.

This "blitz bomber" order is supposed to have imposed massive and critical delays on the Me 262 program, preventing it from having the impact on the Allied bomber offensive of which it was presumed capable. According to this theory, only when the order was rescinded and the plane was produced as a fighter was this problem resolved, but by then it was too late for any significant results.

> However, fortunately for the Allies, the enormous potential of this aircraft was only partially exploited by Germany. ...had the Messerschmitt Me.262 been ... employed immediately in the role to which it was most suited (that of pure fighter), it is highly probable that it would have altered the course of World War II. However, production was dissipated in a series of variants in which it was attempted to adapt the aircraft to various roles, first of all bomber, then that of night fighter. The result was that the 1,430 aircraft built during the last months of the war went into service too late and in too small a number to have any effect on the course of events.[29]

The Me 262 was indeed delayed in production, but it was lack of reliable engines that kept the plane grounded, not Hitler's order. The "blitz bomber" *Fuhrer-Befel* was issued in early June of 1944, and rescinded in early November of 1944. Also overlooked is the fact that it was relatively easy to convert the Me 262 to carry bombs, and a number of aircraft were so modified. A handful of fighter-bomber conversions were made from pre-production models, enough to equip a test squadron, KG 51. This was obviously not the most effective use of this revolutionary new plane, but it imposed no significant delays on its production to equip it in this way. It was lack of reliable engines, far more than any other factor, that delayed production of the Me 262 until it was too late to affect the outcome of the air war.[30]

The potential of the Me 262 to affect the great bombing offensive over Europe was

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undeniable. Even its looks were sleek and menacing, with a distinctly pointed and shark-like fuselage. The pilot sat high in a bubble canopy over the mid-section of the aircraft, and the wings angled gracefully back, with the engines in smooth nacelles hung beneath them. The armament of the Me 262 was impressive - four Mk 108 30 mm cannon. A single hit from one of these cannon was usually sufficient to destroy another fighter, and two or three hits would generally bring down even the largest bomber. This already impressive firepower was augmented by hanging a small wooden rack under each wing, each rack capable of launching a dozen rockets. These rockets could wreak havoc on dense formations of bombers.[31] The Me 262 thus possessed the speed to evade the escorting fighters, and the massive armament to quickly destroy large numbers of bombers. It is not surprising that American Air Force generals spent a good deal of time worrying about what large numbers of Me 262s could do to their air fleets.[32]

As it turned out, the Me 262 had a few serious weaknesses, even aside from the short life and unreliability of its engines. Probably the most serious was another engine-related problem. The Jumo 004 engine, like all other early jet engines, required a very carefully regulated fuel supply. Attempting to rapidly alter the amount of fuel entering the engine could cause the engine to "flame out" or quit. Unfortunately, fighter planes are often required to rapidly alter their speed, and this made the Me 262 a rather tricky and potentially deadly mount. This quirk was discovered after a number of fatal accidents, and a regulator was added to control the fuel flow. This eliminated fuel flow flame outs, but limited the Me 262 to very gradual speed increases or decreases.[33] This inability to rapidly alter its speed made it particularly vulnerable when taking off and landing. In fact, once on a landing approach, the Me 262 lacked the engine power to break out of the landing pattern and resume normal flight. It was, in effect, forced to land. Allied

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pilots, who had taken to patrolling over German airfields in an effort to find targets, were able to take ruthless advantage of this weakness. Many Me 262 were lost to marauding Mustangs and Thunderbolts while taking off or landing.[34]

Despite its problems and weaknesses, the Me 262 was in many respects a revolutionary plane. Not only was it the very first jet-powered combat aircraft to enter production anywhere in the world, but its design incorporated a number of advanced concepts, especially the swept wings. The plane was so capable, that even as late as two and three years after the war ended, it was outperforming the latest American jet fighters in tests, to the consternation of US Air Force generals.

> The results of the Me 262 - P-80A comparative speed and climb tests as outlined in Air Material Command Flight Test Report, Serial No. TSFTE-2008, are viewed with serious concern by this Headquarters. From the performance data submitted in this report it is shown that the German Me 262 is superior to the P-80A in acceleration and speed, and approximately the same in rate of climb. Moreover, the Me 262's performance compares quite favorably with the XP-84 at all altitudes and is superior to the XP-84 in speed at high altitude. The fact that the design for the Me 262 originated in 1939 and that this aircraft even now can outperform our latest fighters reflects most unfavorably on the ability of American aircraft designers and on the American aircraft industry in general.
>
> It is requested that a study be submitted to this office explaining in detail why the Me 262 is superior in performance to our latest fighters. In particular, the following information will be included in this report:
>
> a. An explanation of the design features in the Me 262 that permit it to outperform the XP-84 at altitude.
>
> b. An evaluation of the Jumo 004 jet engine and a performance comparison among the Jumo 004 and the J33 and J35 engines at various altitudes.[35]

The response from Air Material Command, dated 4 December 1946 stressed Germany's

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prewar emphasis on Research and Development (and rather pointedly does not mention the almost total lack of such theoretical work in the United States), the "thoroughly justified" wartime emphasis on mass production of existing models to the neglect of R & D, the post-war emphasis on catch-up in R & D measures, and uses an "we may not be better, but we're faster" argument in comparing the respective development times of the Me 262 and the P-80 (neglecting to mention different circumstances between the two planes and also conveniently not mentioning the XP-84's development, which was behind schedule and rife with problems. The response also includes the requested technical report on the Me 262 and Jumo 004 engines.[36]

Although the Me 262 entered production late in the war, between 1,200 and 1,400 of them were produced. Of these, only between 300 and 400 actually saw combat. Several hundred were with units that were converting to the plane, and were still training when the war ended. Most of the others were lost due to flying accidents or were simply caught in the massive collapse of Nazi Germany, abandoned at factories or airfields.[37] The plane was also subjected to a number of modifications, of which the fighter-bomber variant has already been mentioned. Among the other modifications were a camera-equipped photo reconnaissance aircraft, a two-seat trainer version, both single and two seater radar carrying night fighters, a clear-nosed special bombing aircraft (distinct from the fighter-bomber) and a bomber-destroyer version with a massive 50 mm cannon in the nose.[38]

While the Me 262 was the most numerous and significant of the German jets, the other combat aircraft also deserve mention. The other twin-engined, Jumo 004 powered jet was the Arado Ar 234. Originally designed as an unarmed reconnaissance aircraft, the Ar 234 was extremely successful in that role, being the only late-war German plane capable of penetrating the

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massed Allied fighter defenses and obtaining photographs of Allied territory. The Ar 234 was also converted to the bomber role, at which it was somewhat less successful, due to its limited numbers and bombload. When used as a bomber, the weight of the bombs also slowed it enough to be vulnerable to Allied fighter interception.[39]

The other gas-turbine engined jet plane produced by Germany was the He 162. This People's Fighter was developed in the astonishingly short time of ninety days. It was designed to be a simple and easy-to-build fighter that could be produced in large numbers. This small and graceful plane was powered by a single BMW 003 engine mounted on the top of the fuselage, directly behind the cockpit. Tricky to fly, in the hands of a capable pilot it had excellent performance. A small number of He 162s were produced and one squadron was equipped with the plane, but no aerial combat was conducted by them.[40]

The other two of Germany's jets were technically not jets at all - that is they were not powered with gas turbine engines. Instead they used liquid fuel rockets, being the only operational combat aircraft ever produced with this type of power plant. These two aircraft were the Me 163 and the Ba 349. Both aircraft used the same power plant, the Walter HWK 509 engine. Like all rocket engines, it was extremely simple in concept. Two separate fuels, *T-Stoff* (concentrated hydrogen peroxide) and *C-Stoff* (a mix of methyl alcohol, hydrazine hydrate and water) were mixed in a combustion chamber. When mixed, the two fuels produced explosive combustion. The gas and force of this explosion were channeled out the rear of the combustion chamber, producing massive amounts of thrust.[41] This thrust could be used to power an aircraft.

One of the two aircraft with this power plant, the Ba 349, was considered a "point interceptor," capable of defending a specific target. Designed to be a "disposable" fighter, it was

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constructed largely of wood. Launched vertically from a tall rail, it would rapidly climb to the altitude of the attacking bombers. Selecting a target, the pilot would fire a cluster of unguided R4M rockets, housed in the nose of the fighter. Breaking away from the combat, the pilot would then detach the rear of the plane, which contained the rocket engine and a parachute to return it safely to earth. The pilot would then abandon the forward portion of the plane, and use his own parachute. Although the aircraft was tested successfully, and was intended for combat, no bombers ever flew over its launching sites, so it was denied the opportunity to prove itself in combat.[42]

The other rocket fighter, the Me 163, was a more sophisticated aircraft, with greater capability. This aircraft grew out of the work of Alexander Lippisch, who worked with tailless gliders. One of his glider designs was modified to use an early version of Walter's rocket engine, and proved to have impressive speed. Lippisch was ordered to design an aircraft to utilize a larger version of the rocket engine. The resulting aircraft was small, almost tiny, with a slender, smoothly tapering fuselage and bubble canopy, graceful swept wings and a vertical rudder, but no horizontal tail surfaces. This new design was to demonstrate outstanding speed, reaching 623 mph in level flight during a speed test in 1941.[43] Although not officially recognized because of the war and secrecy of the project, this record would not be broken for over six years, when the United States began to test various experimental aircraft following the war.

The remarkable speed of the Me 163 was not achieved without cost. The chemical reaction that produced this explosive power consumed fuel at a rate of over eighteen pounds *each second*. This meant that even though the Me 163 carried over two tons of propellant, at full throttle it would exhaust this supply in just over *four minutes.*[44] Although this time limit could be

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extended by opening and closing the throttle, which had only an "on" and "off" position, during flight, the aircraft had, at most, ten minutes of powered flight. When the fuel was exhausted, the plane became a high-speed glider, returning to its base without power. While it could climb from a standing start to an altitude of 20,000 feet in a bit over two minutes, its minuscule endurance meant that the plane had to be based directly along the bombers' route to have any chance of attacking them successfully.

Another problem lay with the fuels themselves. *T-Stoff* was an especially dangerous substance. Hydrogen peroxide is extremely unstable and caustic. When in contact with a number of substances, including copper, lead, and anything organic, it decomposes, giving off a great deal of heat. It will also burn human flesh after more than a few second's contact. This dangerous and volatile fuel would cause almost as much harm to Me 163 pilots as enemy guns. Several pilots were badly burned or killed by fuel leaks.

The Me 163's dual nature, by turns a high speed rocket plane and a glider, required that the pilots who flew it have extensive training with both powered and unpowered flight. This sharply limited the number of available pilots for the machine. Although the handling characteristics of the plane were generally excellent, the high speed could cause some problems. Take-off and landing could also be hazardous. The plane rested on a detachable wheeled dolly to take off. After leaving the ground, the pilot dropped the dolly, which was recovered. The wheeled carriage tended to bounce when it hit the ground after being dropped, and occasionally rebounded into the bottom of the aircraft, with sometimes catastrophic results. Landing was even more hazardous than take-off. When landing, a shock-absorbing skid was extended from beneath the center of the fuselage. Although the fuel tanks were empty, they often contained residue or

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vapors. The shock of landing could cause the fuel residue to combine explosively, with unpleasant results for the pilot.

All of these problems could have been acceptable had the Me 163 proved to be an effective weapon. Ironically, the very speed which was so impressive made it difficult to use the plane in combat. German pilots generally preferred to engage the big bombers head on. The bomber's defensive fire was weakest from this angle, and any hits on the Allied plane from this approach were likely to be very damaging. The Me 163's speed, along with that of the bomber, gave a combined closing speed of over 800 miles per hour. Since the two 30 mm cannon which were the Me 163's armament were of relatively low velocity and therefore short range, this made it extremely difficult to line up a shot before being required to initiate break-away maneuvers to avoid a collision. With a head-on approach, a Me 163 pilot had, when in effective range for his weapons, about 1 to 2 *seconds* to line up his target, assess the deflection of the shot, open fire and then maneuver to avoid collision. Even approaching from the rear (which made the fighter much more vulnerable to defensive fire from the bomber) gave a closing speed of almost 400 mile per hour. Although it was generally fast enough to avoid pursuit, the Me 163's speed meant that the pilot had extreme difficulty in using his weapons effectively.

Combined with this problem was the fact that the Allies had a relatively accurate technical description of the aircraft and its capabilities. They were especially aware of its extremely limited range, and confounded attempts to use the plane by simply routing the bombers away from airfields known to house the aircraft.

Ultimately, the tiny "power egg," as the Germans affectionately called the Me 163, would have minimal impact on the war. Although pilots flying Me 163s did score some victories in

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combat, the plane did not cause nearly the panic among Allied flyers that the Me 262 did. After the war, the Allies determined that the liquid fuel rocket engine had little potential as a power plant for military aircraft, and no other combat aircraft would be designed to use it. Rockets were used in experimental aircraft, mainly to test the principles of high-speed flight. The Bell X-1, in which Chuck Yeager broke the sound barrier, is perhaps the best known of these test aircraft.[45]

The above aircraft became operational during the war, and entered combat service, although not all of them actually saw combat with enemy aircraft. The following aircraft did not become operational, but represented Germany's ongoing research efforts in the field of jet propulsion. Some of these planes were flown on test flights, while others were built but not flown. Still others were designs that were never constructed.

The Heinkel He 280 was created to compete for the jet fighter contract, along with the Me 262. It's design was similar to the Me 262 in many ways, but it had several significant differences. Like the Me 262, it was a single-seat, twin-engine fighter. Also like the Me 262, the engines were hung underneath the wings in nacelles. Unlike the Me 262, the He 280 had twin rudders, mounted at the ends of the tail surfaces. The most significant difference between the two aircraft was that while the Me 262 had swept wings, the wings of the He 280 were straight. This difference in wing design gave the Me 262 considerable performance superiority. As a result, the Me 262 won the competition. A few He 280s were built as part of the testing and competition, and were tested and flown extensively. As its performance was inferior to that of the Me 262, no further work was done on it.[46]

The Horten IX / Gotha Go 229 was another jet fighter that was built and flown for test flights but did not become operational. In this case it was not the performance of the plane that

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prevented it from being produced, but rather the end of the war. In appearance, this was perhaps the most radical of all German jet designs. It originated with the efforts of two brothers, Reimar and Walter Horten. The brothers, much like Alexander Lippisch, were fascinated by the possibility of constructing a tailless, flying wing design. They were able to develop the concept even further than Lippisch had, and produced a series of flying wing gliders of increasing size. Eventually they were able to interest officials of the Luftwaffe in their work, and the ensuing evaluation suggested coupling the Horten's designs with jet engines. This led to the Horten IX, a flying wing powered by two Jumo 004 engines. This prototype was destroyed in a landing accident after only a few flights, but even this short career was sufficient to convince officials that it should be produced.

The Horten flying wing was ordered into production by *Gotha Wagonfabrik*, and given the designation Go 229. It was a pure flying wing, with no fuselage or tail surfaces at all. The overall appearance was very similar to a giant boomerang, with the wings angling to the rear. The center section of the plane, housing the pilot and engines, was constructed of metal, while the outer portions of the wings were to be a wood composite. The pilot sat in the forward center of the wing, under a bubble canopy. Two Jumo 004 engines, located on either side of the cockpit, provided the power. The air intakes were in the leading edge of the wing and the exhaust ports located on the upper surface of the wing. Preliminary tests indicated that the plane would possess excellent speed, in the vicinity of 600 mph, and superb handling characteristics. Several advanced prototypes, including day fighters, night fighters, and two seat trainers, were under construction when the factory was overrun by the Allies.[47]

Another fighter prototype was the Me 263. As the number implies, this plane was a

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further development of the Me 163 rocket fighter. German aircraft of this period were assigned a designation composed of letters, which were an abbreviation of the manufacturing company's name (Me - Messerschmitt, Fw - Focke Wulf, Ju - Junkers) and numbers. The numbers were assigned by the RLM sequentially, based on when the project was proposed. The higher the number, the more recent the design. Thus the Do 17 was a fairly old design, while the Me 262 was much newer. It was also standard practice to designate major revisions or redesigned versions of an aircraft by adding hundreds digits to the original number. Thus redesigns of the Do 17 became the Do 217, the Ju 88 the Ju 188 and the Me 163 the Me 263.

The Me 263 was of more conventional appearance than its predecessor, with a cylindrical fuselage, swept wings, and a vertical rudder with no horizontal tail surfaces. In an attempt to improve the ground handling of the plane, retractable landing gear was included, rather than the jettisonable dolly / landing skid arrangement of the Me 163. In an effort to overcome the range limitations of the Me 163, the Me 263 was powered by two rocket engines. The first was to be used for takeoff and climb to altitude, while the second was to be used for propulsion once the plane was at operational altitude. The Me 263 was tested, and found to have the increased endurance desired, but in many other respects was similar to the Me 163, and in some crucial areas, such as maximum speed, actually had poorer performance. As a result, the Me 263 was never put into production.[48]

The final jet that flew test flights was not a fighter at all, but the word's first purpose-designed jet bomber, the Ju 287. The most unusual feature of this aircraft, which was initially propelled by four Jumo 004 engines, was the wing design. In an attempt to improve speed and handling characteristics, the wings were given a forward sweep. That is, they were attached near

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the rear of the fuselage, and angled forward from there, creating a very unusual looking aircraft. Two of the engines were hung under the wings, and two more attached to the forward portion of the fuselage, near the crew cabin. To save time, many of the prototype's components were borrowed from other aircraft, including a nosewheel from a captured American B-24. The plane made a number of test flights, and was considered successful. It had high speed and reasonable handling characteristics. Modifications were planned to correct the most significant problems, including the addition of another pair of engines to be hung under the wings. Having reached this stage of development, the project was canceled in mid-1944, when Germany abandoned work on bombers to concentrate on fighters. The project was strangely resurrected in early 1945, only to have the factory overrun by the Soviets.[49]

One German jet that was never completed but would nonetheless have a significant influence on future jet designs was the Messerschmitt P 1101. This was a single-seat high performance fighter, designed to use the new Heinkel-Hirth 011 engine. As the engine was never completed, the single P 1101 prototype sat in a factory until captured by the Americans. The most interesting feature of this plane was that it was intended to test the concept of *variable sweep* for the wings. That is, the angle of the sweep of the wings could be changed, to evaluate the effect of various wing angles on flight. The captured prototype was taken to the United States and given to Bell Aircraft. An attempt to make the German machine flyable failed due to damage to the aircraft, and so Bell copied the design and produced their own version of the plane. This was given the designation X-5, and the major change, apart from the use of an American engine, was to make the variable sweep controls capable of operating in flight. The German machine needed to have the wing angle altered on the ground and locked into place, but the X-5

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could change the wing angle while airborne. These tests would later lead to such advanced variable sweep American jet planes as the F-111 and F-14.[50]

Other German jets that were built or ordered into production include the Focke Wulf Ta 183, a swept-wing, high performance fighter plane. Although ordered into production, the factories were overrun by the Soviets before any machines could be completed. The Soviet MiG-15, which would give the United Nations such difficulty over Korea five years later, bears a strong resemblance to the Ta 183.[51] Although the Soviets have insisted that the MiG-15 was an entirely new and original design, the Soviet tendency to borrow, steal or reverse engineer military technology they did not possess makes that claim questionable.

Examples of such borrowing or reverse engineering include the Yak-15 fighter, which was a Soviet Yak-9 fighter with a German Jumo 004 engine hung below the fuselage in the nose, the AK-47 assault rifle, which was inspired by and took several major design components from the German Sturmgewehr 44 assault rifle, and the Tupolev Tu-4 heavy bomber, which was a complete copy of the Boeing B-29 Superfortress. The Tu-4 was produced from several American B-29s that were forced to land at Vladivostok following raids on Japan. The bomber crews were returned but the aircraft were kept and used as models for a Soviet copy.

The Henschel Hs 132 was a jet-powered dive bomber. In appearance it was very similar to the He 162, with its single engine mounted on the upper fuselage behind the cockpit. The major difference between the two was that in the Hs 132 the pilot lay prone in the nose of the aircraft. This was done to increase the pilot toleration of g loads, the pressure created by high-speed dive pull-outs. While a seated person could only tolerate 5 to 6 gs before blacking out, a prone person could handle 9 to 10 gs. One prototype Hs 132 was built, but was captured by the

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Soviets before it could be flown. It is not known whether the Soviets flew the aircraft.[52]

Other German designs that never saw the light of day included ram jets, pulse jets, flying wing bombers, large multi-engined bombers that bear a strong resemblance to later American designs such as the Boeing B-47, and a number of even more unusual concepts. Much of this design material was captured by either the Americans or the Soviets, and would provide the initial impetus for the jet race of the early Cold War.[53]

The British and the Germans were not the only countries experimenting with jet propulsion during the war years, however. Most of the other major combatants had their own programs to research jet powered flight, but the output of these programs was minimal.

The Italians produced what has frequently been claimed to be the world's first jet powered aircraft. This was the Caproni-Campini N.1. In appearance it resembled a long, hollow cigar with relatively stubby wings, tail surfaces and a two seat cockpit. Although it had the external appearance of a jet aircraft, it was in fact powered by a traditional internal combustion piston engine, but rather than power a propeller, the engine operated a number of air compressors, which created a flow of air through the fuselage. Fuel was ignited and the burning fuel added to the air flow to heat it. While many of the basic components of a jet engine are present in this design, the end result is rather different, and essentially worthless. The N.1. made a number of test flights, and virtually every one of them was marred by the failure of one or more of the aircraft's systems. The top speed of the aircraft was only about 230 mph, and it could fly less than 150 miles before running out of fuel. Fascist Italy's attempt to create a jet aircraft did not in fact have a jet engine, and was functionally useless as well.[54]

The Soviet Union was also experimenting with the design of jet engines during the war,

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but the urgency of other demands gave this work relatively low priority. The Red Air Force did not have to contend with German jets until the closing days of the war, so there was little need for a Russian jet in any case. However, German, British, and American work in this field led the Soviets to play frantic catch up immediately following the war. Their first efforts in the field of jet powered flight were brutally simple. Lacking a functional jet engine of their own, they simply took captured German engines, mostly Jumo 004s, and placed them in the nose of existing piston engined aircraft, usually the Yak-9 fighter. As the engine had to be hung below the wing in order to have a clear outlet for the exhaust gases, this gave the plane, designated the Yak-15, the appearance of a flying frying pan when viewed from the side. While it flew, its performance was roughly comparable to existing piston-engined aircraft.[55] As the Second World War drew to a close, the Russians, determined to achieve parity with the other powers, threw themselves into this new field of aviation. They were aided by the British aviation industry, which sold them a number of their very latest jet engines in the years immediately following the war. The plane that was such a shock to American airmen over the skies of Korea, the MiG-15, was powered by a licence-built copy of the Rolls Royce Nene jet engine.

The other nation to experiment with jet propulsion during the war was Japan. Japan produced three different jet-powered aircraft, one of its own design and two largely copied from German designs. Only one of these designs entered combat before the war ended, although the other two were in flight testing, and would have been ordered into production. The two German-inspired designs were the Mitsubishi J8M *Shusui* (Sword Stroke), a rocket-powered interceptor which was a licence-built copy of the Me 163 *Komet*, and the Nakajima *Kikka* (Orange Blossom) inspired by, but not directly copied from, the Me 262 *Schwalbe*. The original design was the

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Yokosuka MXY7 *Ohka* (Cherry Blossom). The *Ohka* was a rocket powered *kamikaze*, or suicide, weapon.

Work on the *Shusui* began in 1943, when the Japanese obtained the right to build the Me 163B airframe and the Walter HWK 509 rocket engine. It was intended to use this plane to combat the B-29s that would soon appear to ravage the home islands from high altitudes. One of the two German submarines en route to Japan with the technical data about the airplane was sunk, and so only incomplete information on the machine reached Japan. This information was enough to begin construction, however. The first prototype, completed in December 1944, was constructed as a glider, and tested after being towed to altitude. Handling characteristics were good, and a rocket powered version was constructed for testing. On the first test flight, the rocket engine quit after a steep climb, with a fatal crash resulting. No further powered flights were conducted before the war ended.[56]

The *Kikka* was based on a German design (the Me 262), but much less closely than the *Shusui* had been. While the *Shusui* was as close a copy of the Me 163 as the Japanese could manage on the information they had, the *Kikka* was simply inspired by its German counterpart, the Me 262. The basic layout was similar, but there were important differences. One of the largest of these differences was the planned role of the plane. The *Kikka* was conceived as an unarmed bomber, not as a fighter. Another difference was the wing layout. The Me 262 had swept wings, while those of the *Kikka* were basically straight. Finally, the engines of the *Kikka* were much less powerful than those of the Me 262, resulting in a top speed of only about 400 mph.[57]

A single *Kikka* made several flight trials, but was still in the testing stages when the war ended. A number of other machines were under construction, including various models such as

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two seat trainers, reconnaissance machines and an armed fighter. With the engines used, the *Kikka's* performance was in the same range as the best American piston-engined fighters, and would have been in a difficult situation in combat. The *Kikka's* survival would have been rendered even more problematic by the arrival of the American P-80 Shooting Star jet fighter, which was scheduled to begin squadron service in the Pacific shortly after the war ended. The Japanese were also working on a much closer copy of the Me 262, the Nakajima Ki 201 *Karyu* (Fire Dragon). This was much closer than the *Kikka* in appearance and performance to the Me 262, but although under construction, none were finished before the war ended.

The final Japanese jet aircraft was an original design, the *Ohka*. This aircraft was part of the larger *kamikaze* (divine wind) program of suicide attacks on American ships. Often called the *Baka* (Fool) by Americans, the *Ohka* was more of a manned missile than a complete aircraft. It resembled nothing so much as a cigar with wings and a cockpit. Incapable of taking off or landing under its own power, it was intended to be carried in the bomb bay of a larger bomber, to be dropped at a short distance from targeted American ships. It would proceed towards the chosen target, first by gliding, then with the aid of several small solid fuel rockets. The goal of the pilot was to crash his craft into a ship, detonating a large warhead in the nose of the plane, damaging or sinking the ship. The *Ohka* was used a number of times, causing some damage to American vessels, but the vulnerability of the launching bomber and the need for it to get relatively close to the target vessels meant that most *Ohka* never got a chance to perform their mission. The Japanese were developing a number of variants of the *Ohka*, including trainers and jet powered versions as the war ended.[58]

Efforts to build effective jet fighter planes were undertaken by many of the combatants

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during the Second World War. The British accomplished the most of any of the Allied powers, producing the first effective and reliable jet engine and a solidly performing jet fighter, the Meteor. The Germans, although troubled by material shortages, managed to produce a number of advanced and effective jet aircraft, enough to deeply trouble the Allies, but fortunately for the Allies not enough to seriously affect the outcome of the war. All of this work would influence, directly or indirectly, American efforts to produce jet fighter aircraft.

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26. Comparisons between the two airplanes are as follows: Power plants: Meteor - two Rolls-Royce Derwent I engines developing 2000 lbs thrust each, Me 262 - two Jumo 004B engines developing 1980 lbs thrust each; Speeds: At sea level, Meteor - 458 mph, Me 262 - 514 mph; at 20,000 feet, Meteor - 493 mph, Me 262 - 540 mph. Ethell and Price, ***Fighting Jets***, pp. 53, 106.

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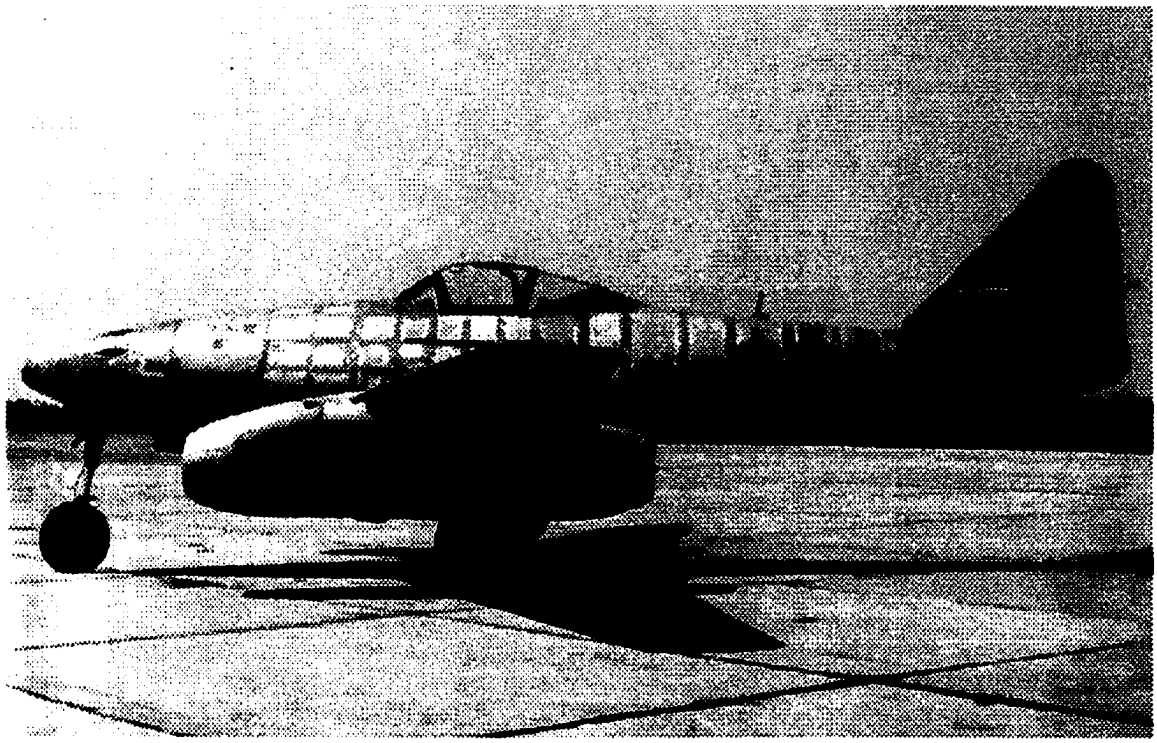
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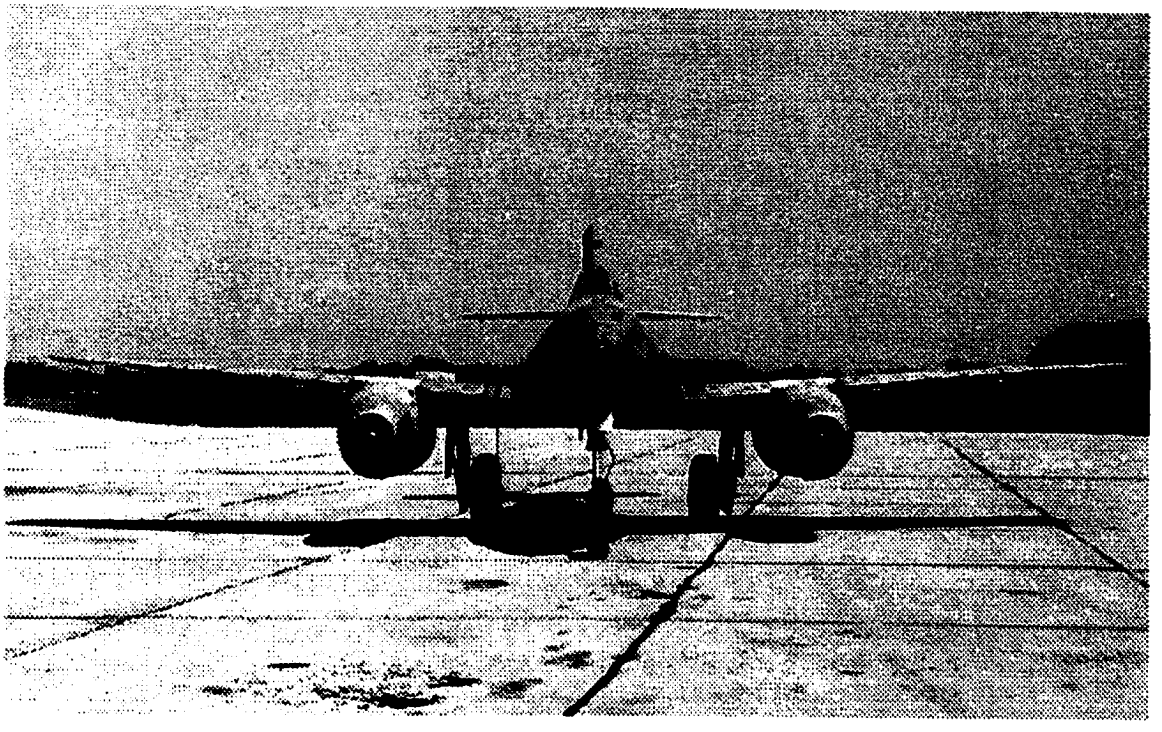
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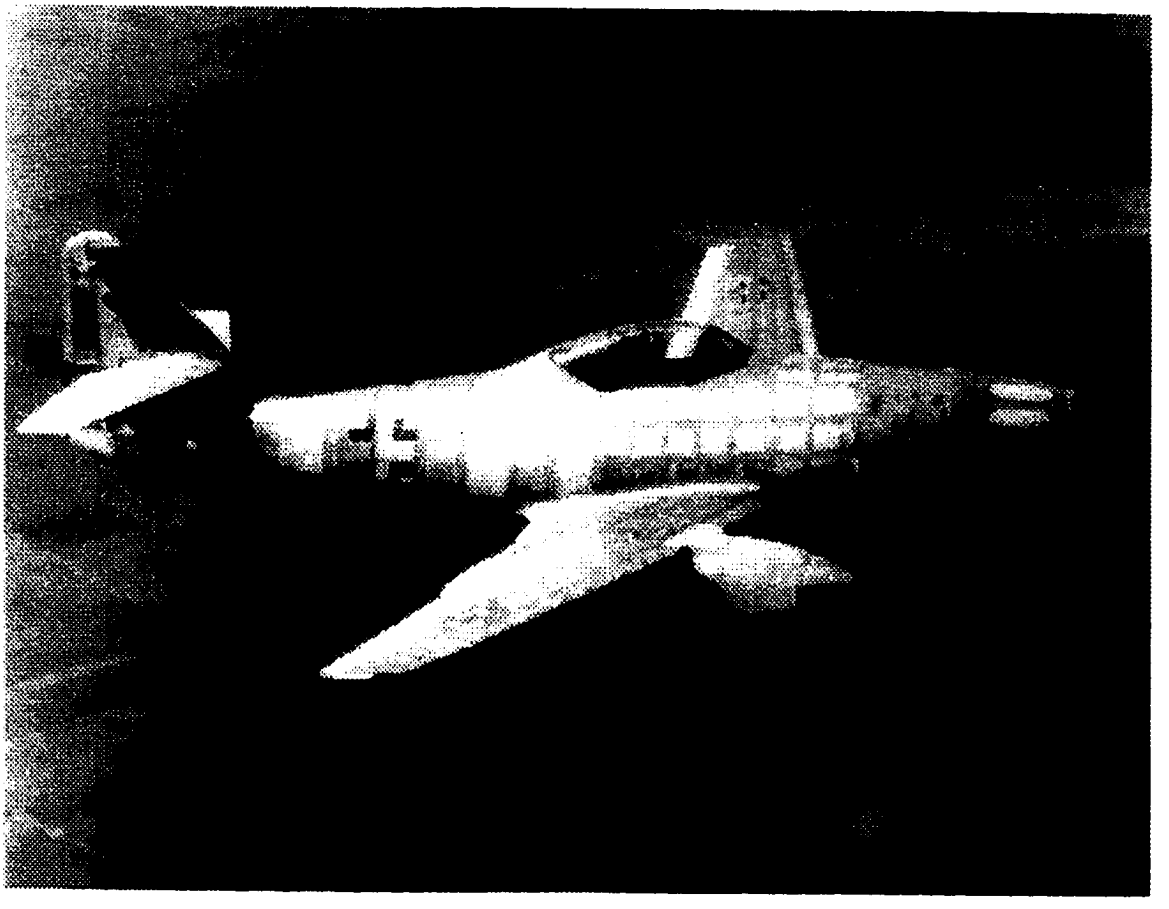
An Messerschmitt Me 262 *Scwalbe*, captured by American forces and brought back to the United States for testing after the war. Th sleek, shark-like lines of the aircraft are especially evident in this view. Photo credited to Bureau of Public Relations, dated 31 August 1945. (National Archives, Photographic Division, Box 2052, Number 34780)

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The menacing head-on profile of the Me 262. The openings for the four 30mm cannon just above the nose are obvious, as is the bulk of the Jumo 004 engines under the wings. Photo credited to Bureau of Public Relations, dated 31 August 1945. (National Archives, Photographic Division, Box 2052, Number 34781)

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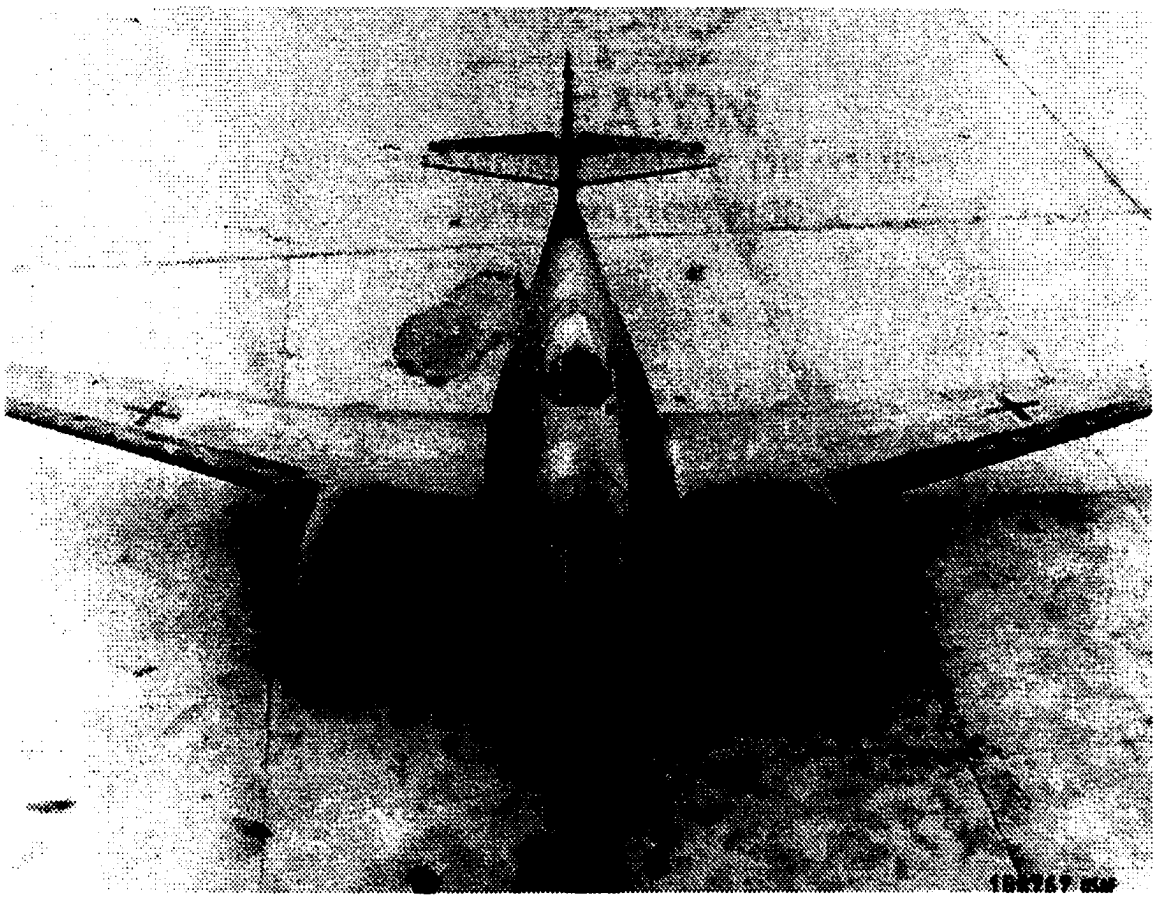
The captured Me 262 being flight tested. Note that the cannon have been removed and the openings faired over. Photo credited to Wright Field, dated 12 September 1945. (National Archives, Photographic Division, Box 2052, Number 34784)

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The Me 262 in flight, from beneath. The mild sweep back of the wings is apparent in this shot. Photo credited to Wright Field, dated 12 September 1945. (National Archives, Photographic Division, Box 2052, Number 34787)

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Another shot of a captured Me 262, from above. The full length leading edge slats are deployed in the down position. Photo credited to Wright Field, dated 6 March 1946. (National Archives, Photographic Division, Box 2052, Number 34803)

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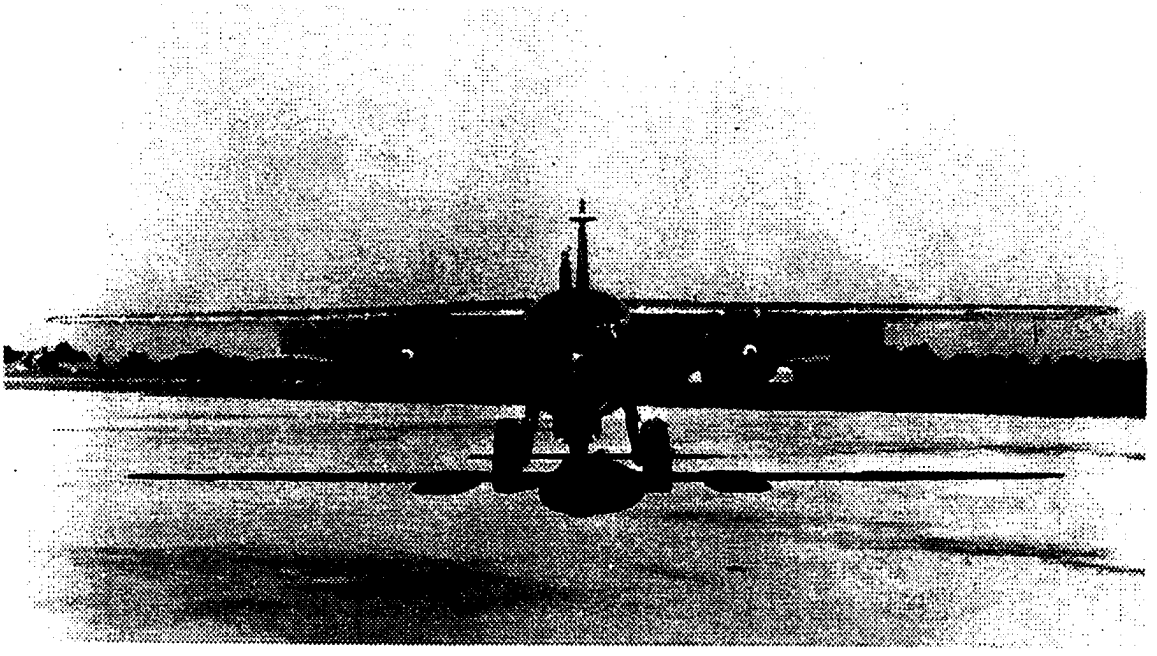
Another captured Me 262, this one the two seat version adapted for the night fighter role. The distinctive German "stag horn" radar antennas are prominent in the nose. The "FE" number under the tail is an American designation, which stands for "Foreign Equipment", and was applied to all non-American aircraft obtained and evaluated by the Air Force. Photo credited to Wright-Patterson Air Force Base, dated 8 August 1960. (National Archives, Photographic Division, Box 2221, Number 21493)

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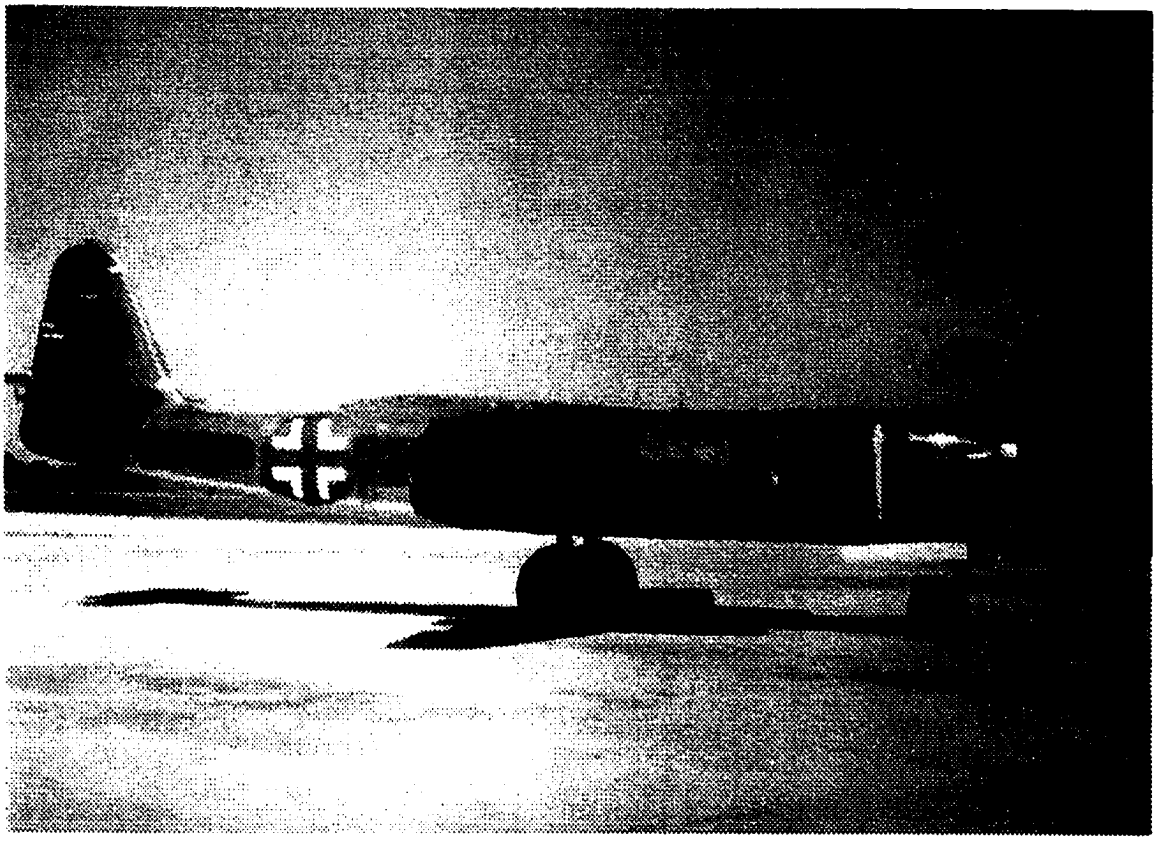
German Arado Ar 234B *Blitz* jet reconnaissance/bomber, being evaluated in the United States. The splotched camouflage paint scheme is not authentic, as all Ar 234s were factory painted in a hard edged "splinter" scheme. Despite its large size, it is a sleek and streamlined aircraft. Photo credited to Wright Field, dated 5 October 1945. (National Archives, Photographic Division, Box 2049, Number 34283)

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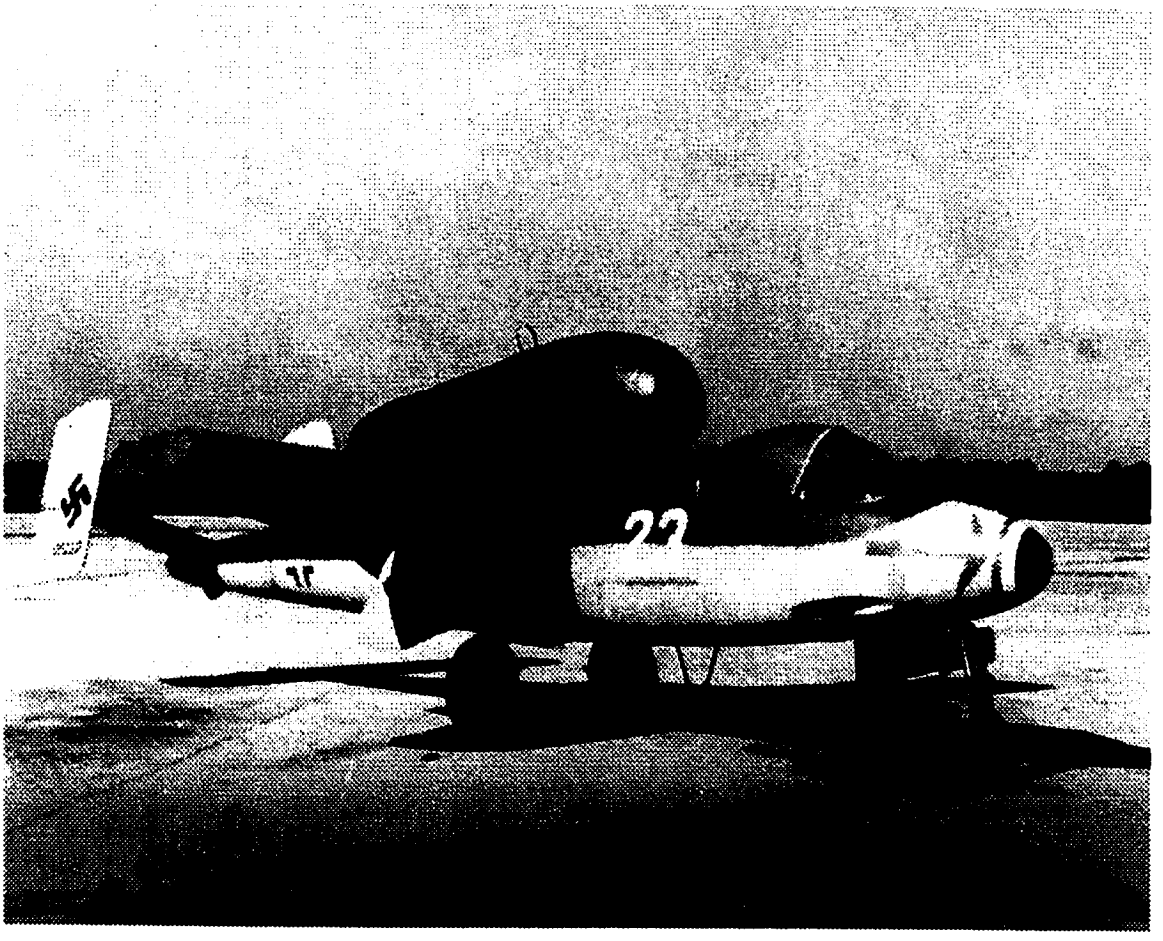
The Ar 234B from the nose. Despite the narrow track landing gear, it handled quite well on the ground. The short spike poking up from the top of the fuselage, just to the left of the taller vertical tail surface, was a mirrored periscope to provide the pilot with some vision to the rear. Since the crew compartment was on the nose of the aircraft, the pilot had no other means of looking behind the plane. Photo credited to Wright Field, dated 5 October 1945. (National Archives, Photographic Division, Box 2049, Number 34279)

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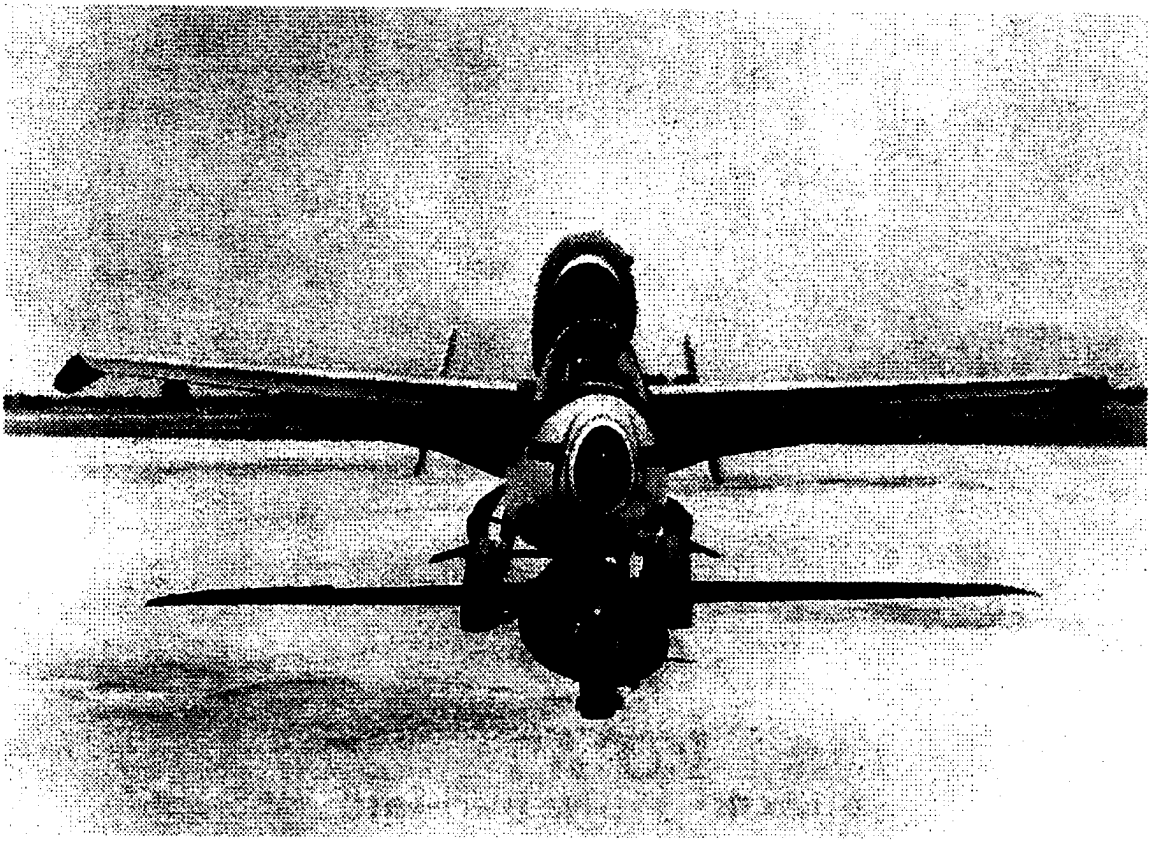
Another side profile of the Ar 234B. Again, the periscope housing rises from the forward cabin. Photo credited to Wright Field, dated 8 August 1960. (National Archives, Photographic Division, Box 2221, Number 21475)

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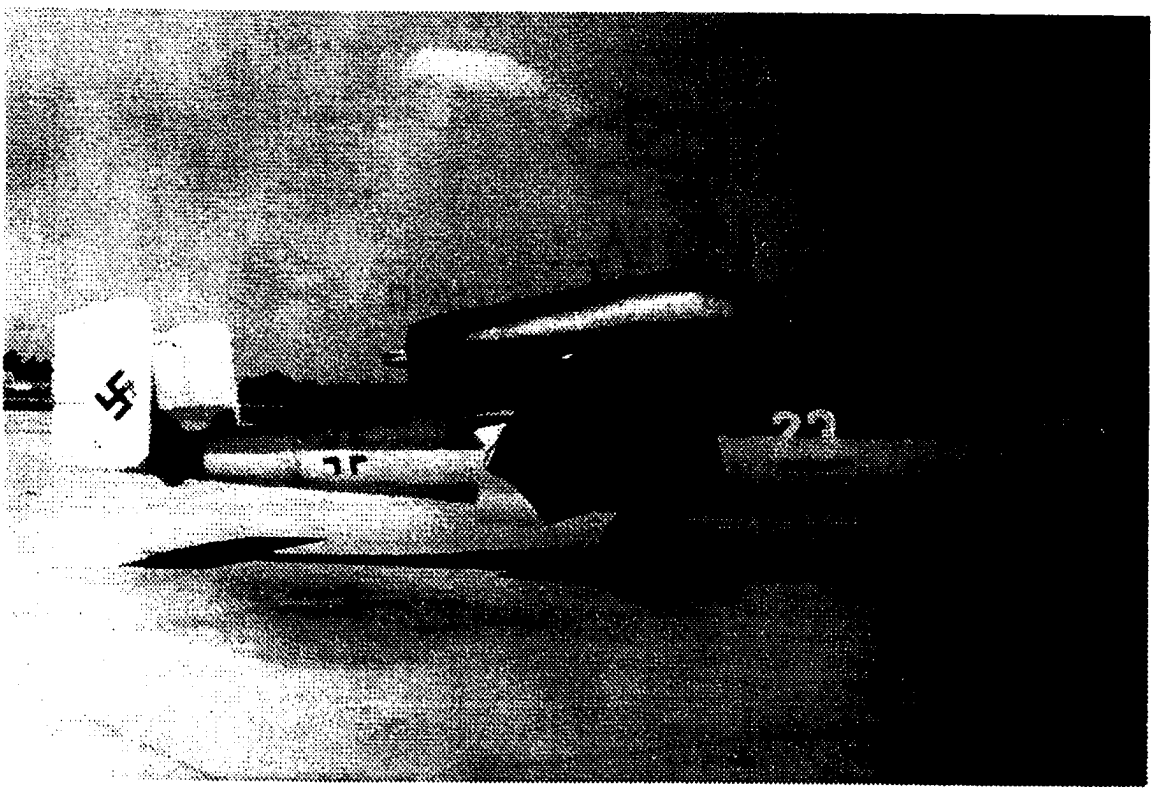
Another German jet on American soil. A Heinkel He 162 *Volksjager* at Wright Field. The prominent location of the engine on the fuselage spine, and the split twin tails to allow the venting of the exhaust gas, are obvious. A 20mm cannon can be seen poking out below the cockpit. Photo credited to Wright Field, dated 5 October 1945. (National Archives, Photographic Division, Box 2050, Number 34517)

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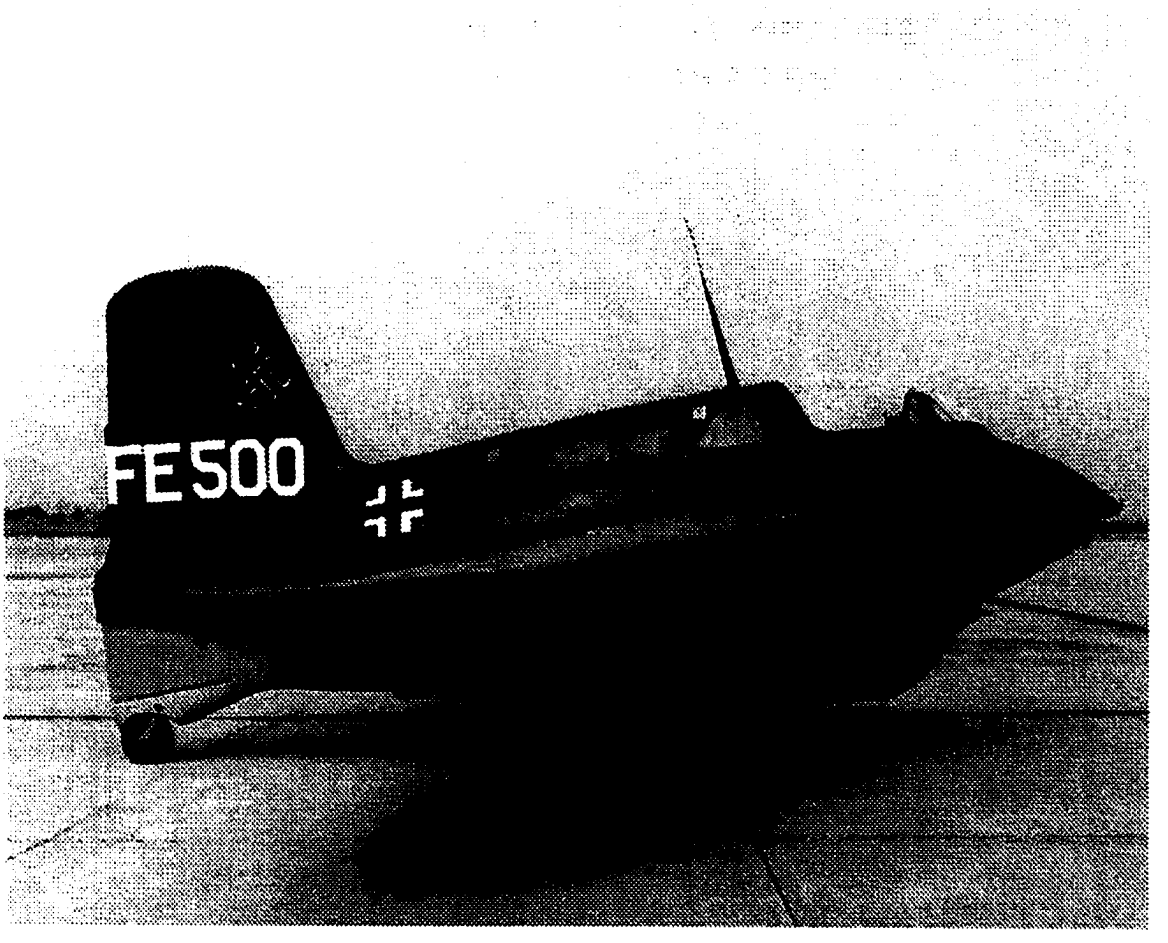
The He 162 from the nose. The downward angled wingtips were added to give more stability in flight. The difficulty a pilot would have had abandoning this aircraft it flight can be imagined, trying to exit a cockpit directly in front of the intake for a jet engine. (National Archives, Photographic Division, Box 2050, Number 34518)

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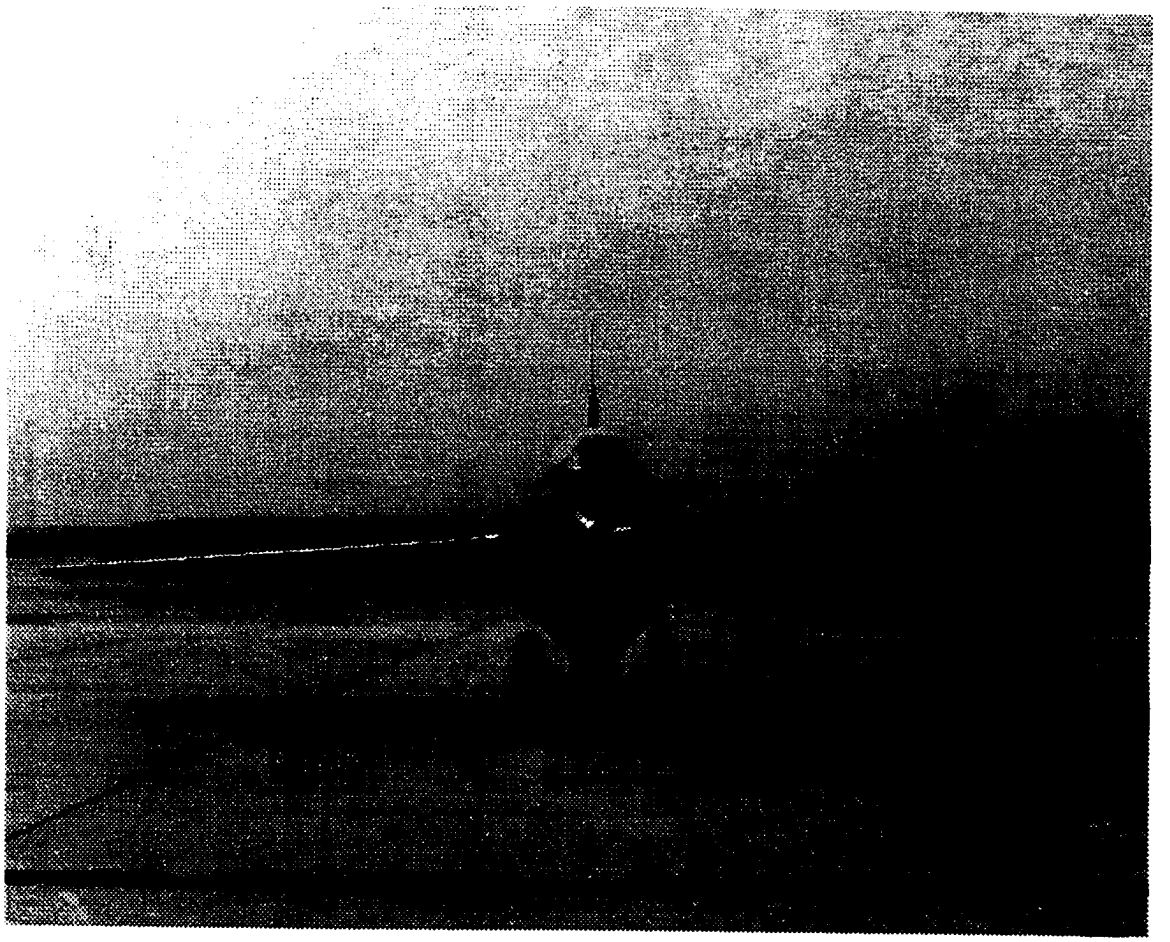
The graceful He 162 from the side. Built largely from wood composite, it went from paper concept to flying prototype in 90 days, and was in full production a month later. Photo credited to Wright Field, dated 8 August 1960. (National Archives, Photographic Division, Box 2221, Number 21484)

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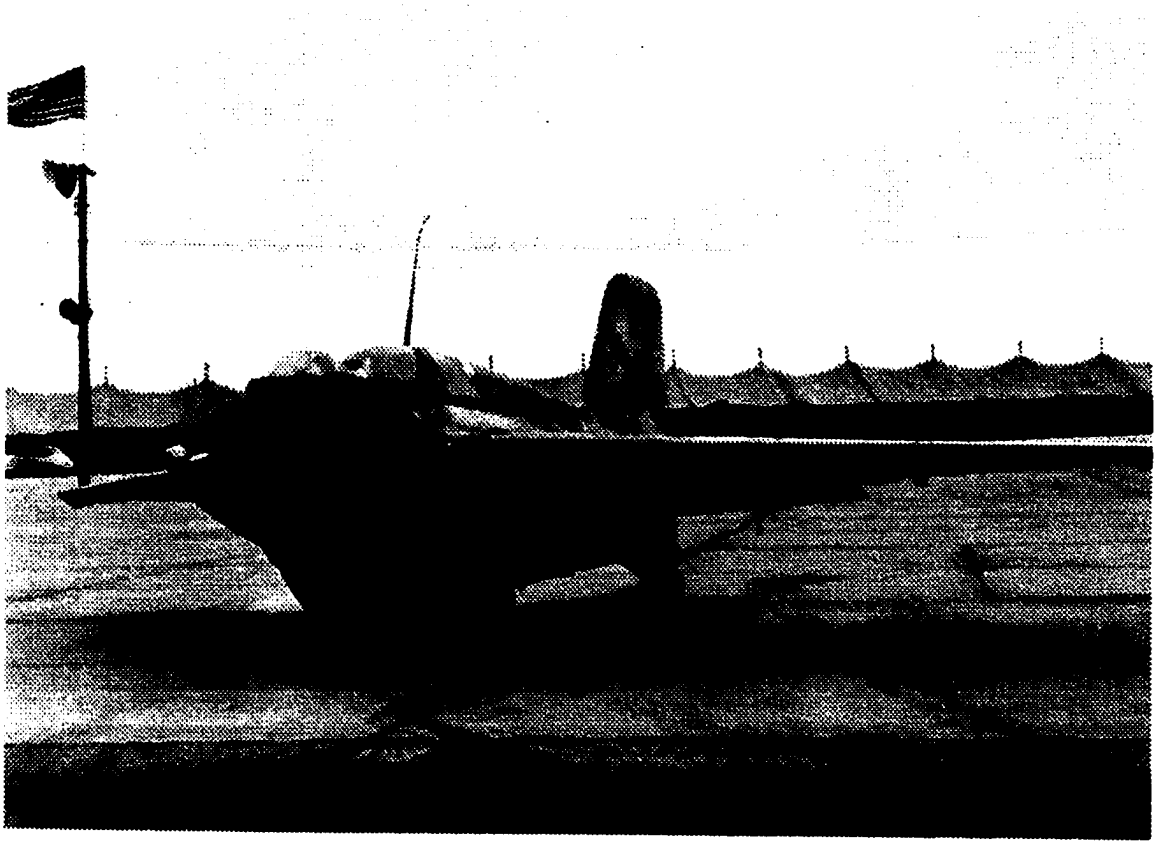
German Me 163B *Komet*. The small size of the airplane is apparent. The retractable landing skid can be seen on the bottom of the fuselage, forward of the large tires. Although Me 163s were brought to America for evaluation, none were ever flight tested, as they were considered to be too dangerous to be flown safely. Photo credited to Wright Field, dated 8 May 1946. (National Archives, Photographic Division, Box 2052, Number 34746)

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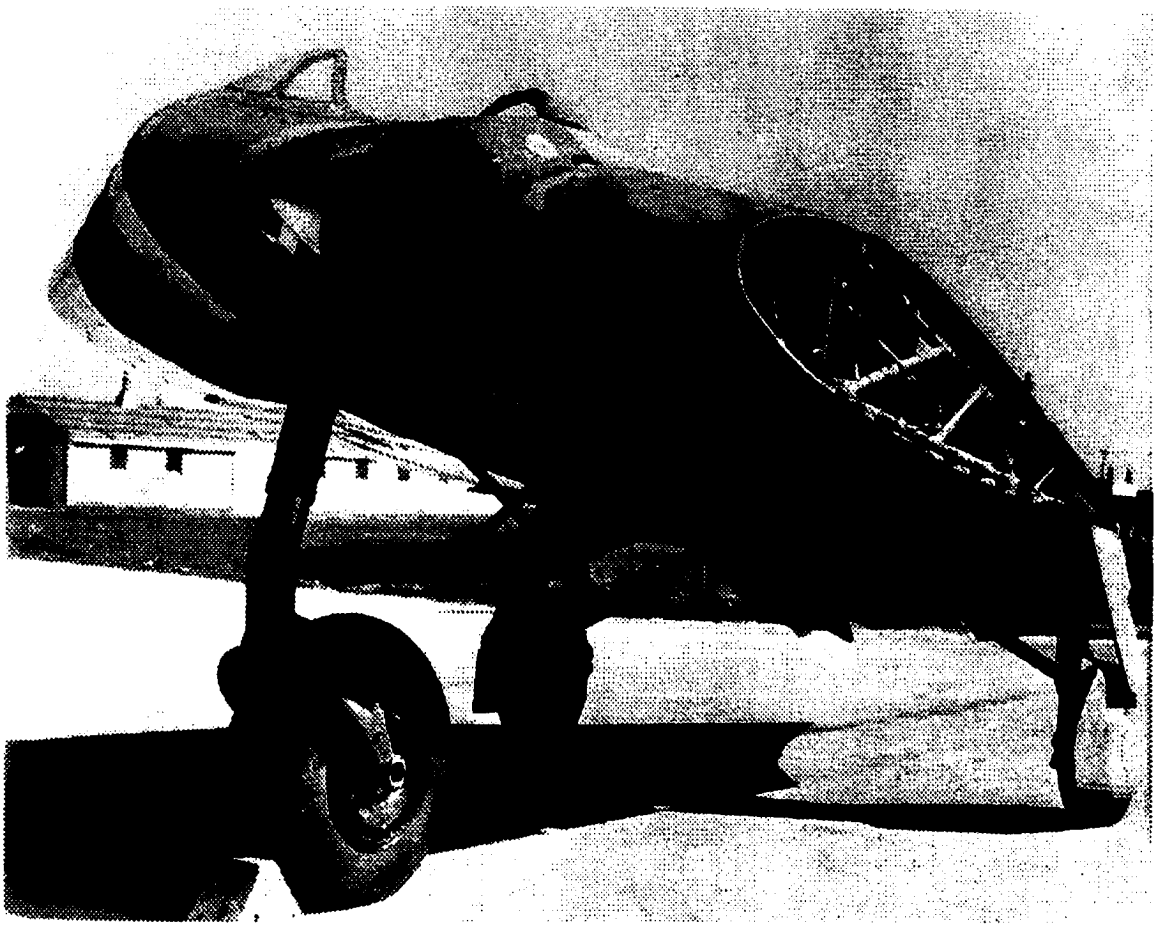
The Me 163B from the front. The graceful lines of the plane are apparent. The jettisonable wheeled carriage can be seen attached to the bottom of the plane. The tiny propeller on the nose was a wind-turned generator, to provide electricity to operate the instruments while in flight. Photo credited to Wright Field, dated 8 May 1946. (National Archives, Photographic Division, Box 2052, Number 34750)

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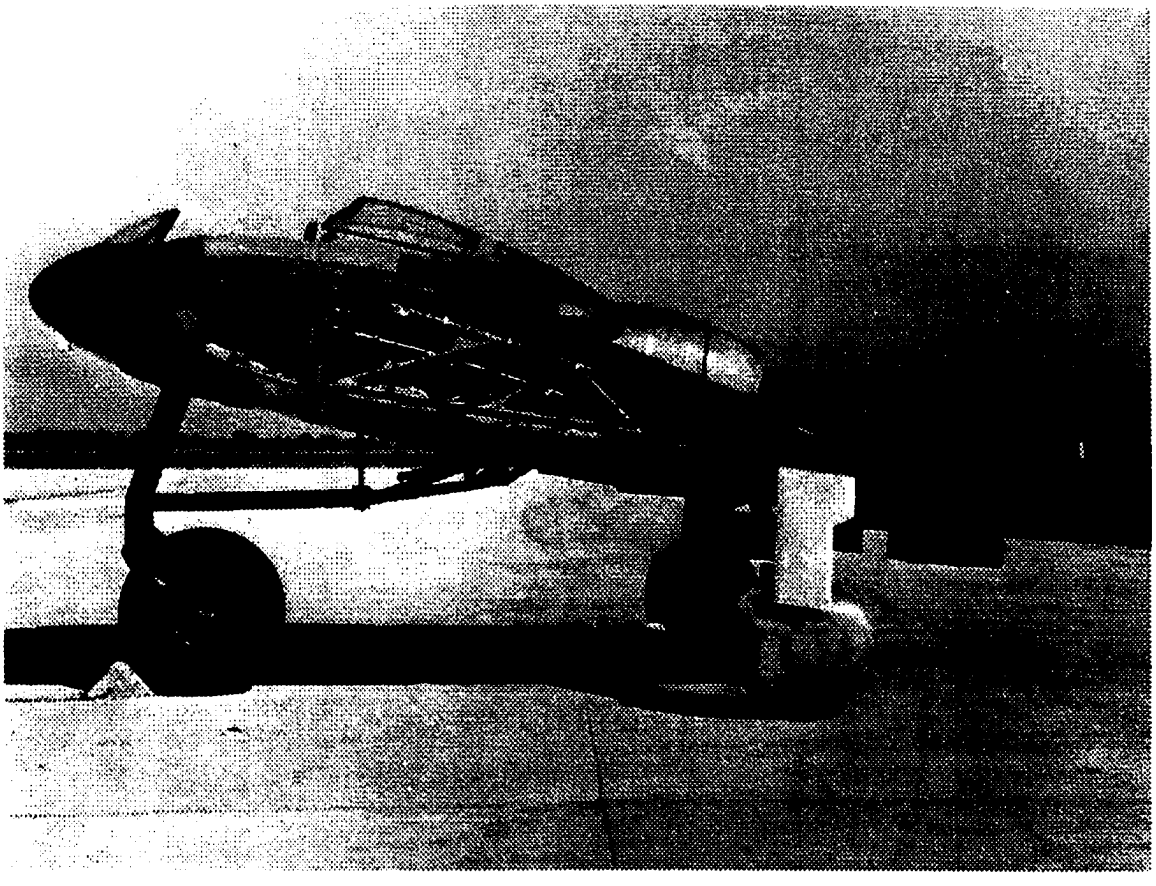
Front oblique view of an Me 163B. The opening for the 30mm cannon in the root of the wing can just be made out. Photo credited to Wright Field, dated 22 October 1945. (National Archives, Photographic Division, Box 2052, Number 34754)

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The central section of the German Gotha Go 229 flying wing jet fighter. The missing outer wing sections were made from a wood composite material. The intake for one of the two Jumo 004 engines can be clearly seen below the cockpit. This particular aircraft remnant is currently in storage in the Paul Garber facility of the National Air and Space Museum of the Smithsonian Institution, awaiting (as are many other historic planes) the funds and personnel for complete restoration. Photo credited to Wright Field, dated January 1946. (National Archives, Photographic Division, Box 2050, Number 34564)

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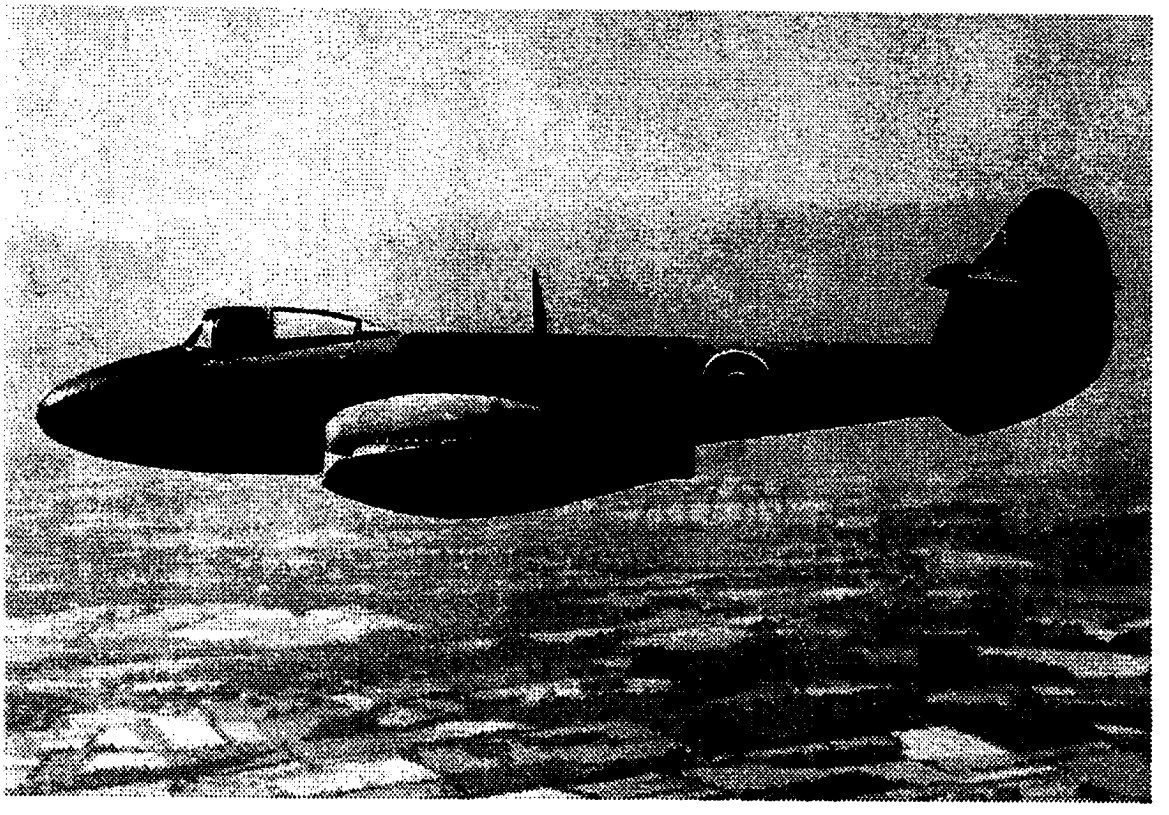
The Go 229 center section from the side. The aircraft's design allowed the Jumo 004 engine to be buried in the wing itself, greatly reducing drag. The exhaust outlet can be seen above the wing just above the rear landing gear. Photo credited to Wright Field, dated January 1946. (National Archives, Photographic Division, Box 2050, Number 34568)

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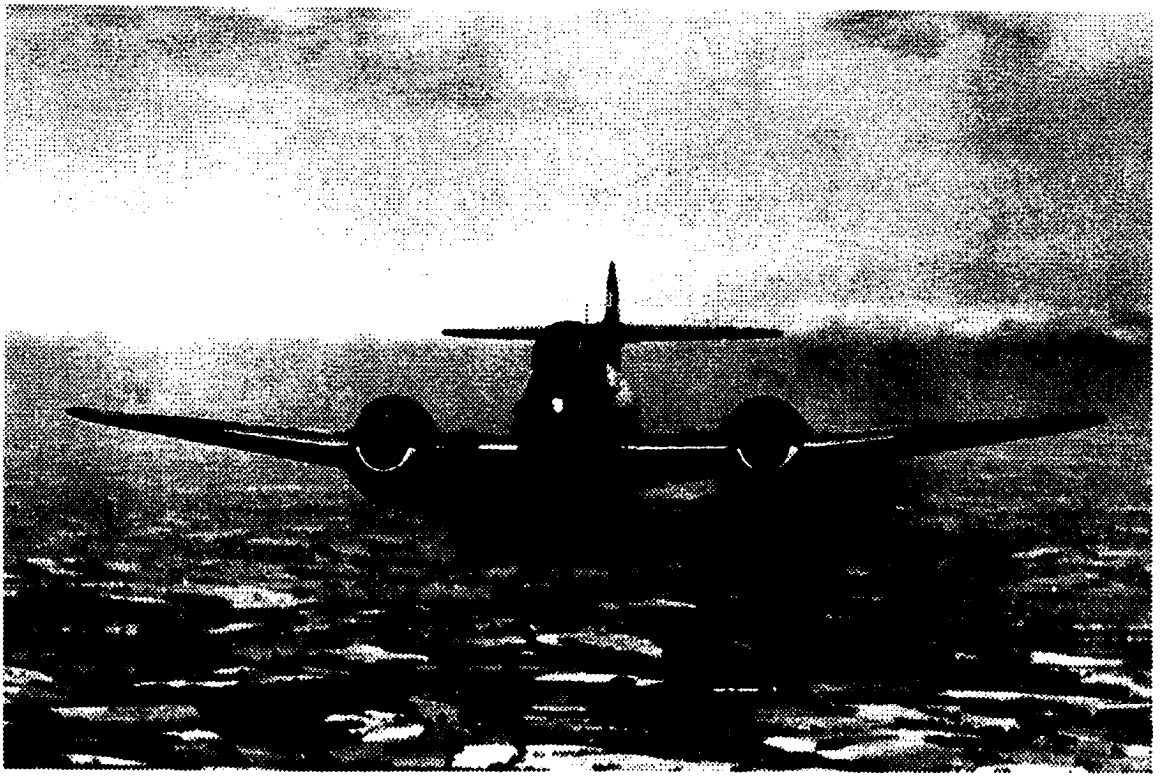
A British Gloster Meteor jet fighter. Photo credited to British Ministry of Supply, Aircraft and Engineering Section, dated 31 January 1947. (National Archives, Photographic Division, Box 2046, Number 33550)

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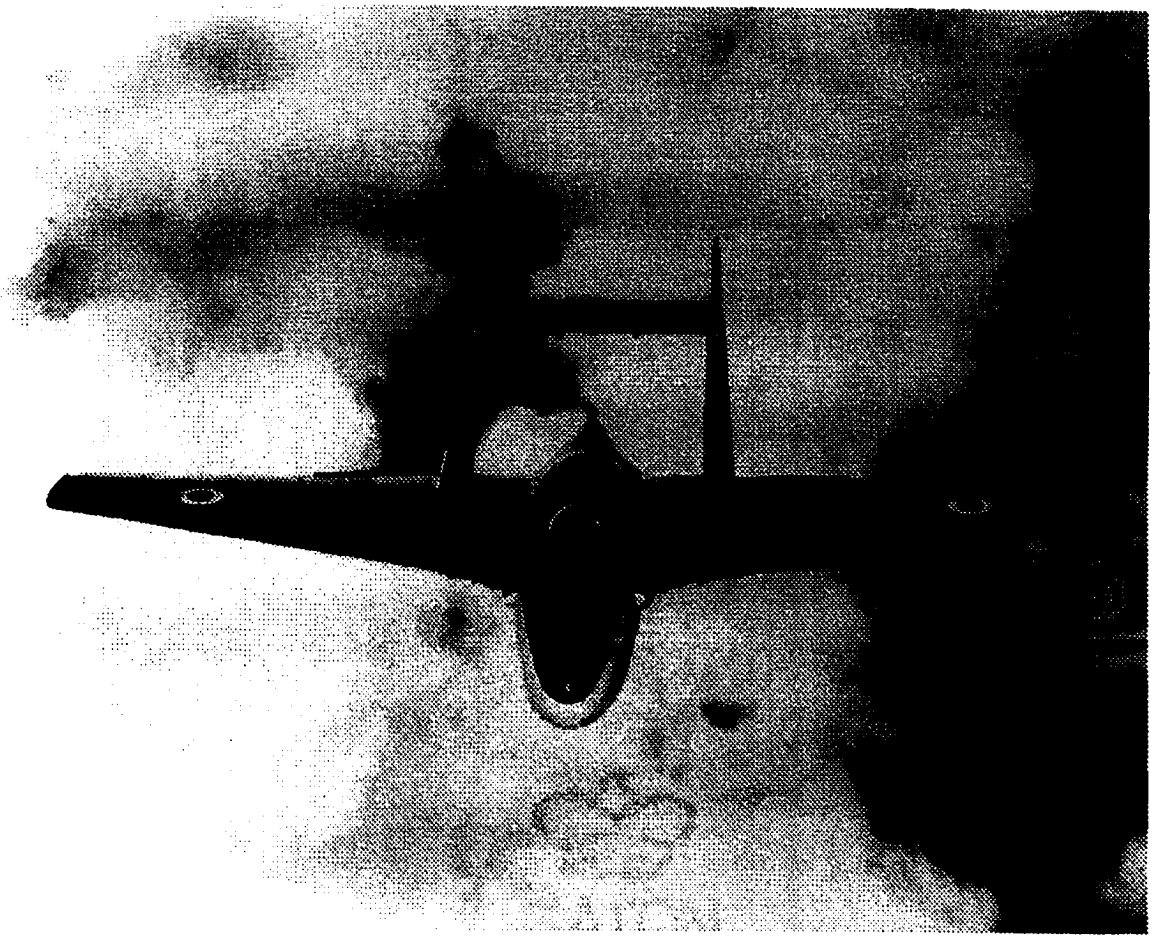
Gloster Meteor in flight. Note the earlier style more heavily framed canopy, and the gun ports for the 20mm cannon in the side of the nose. Compare the shape of the Meteor's engine nacelles, short, bulky but tapering rapidly, to the longer and more slender nacelles of the Me 262. Photo credited to Bureau of Aeronautics, Navy Department, dated 16 February 1945. (National Archives, Photographic Division, Box 2046, Number 33564)

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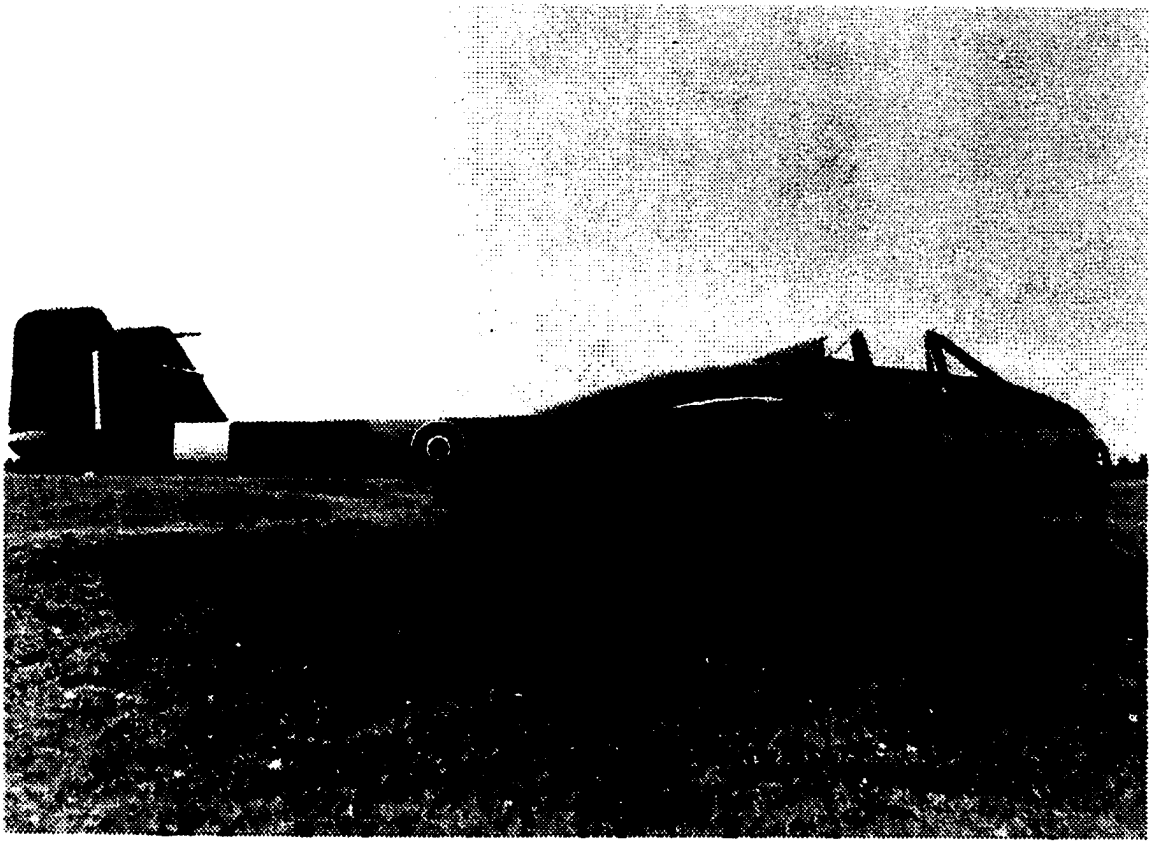
Head-on profile of a Meteor in flight. The Meteor's wings were considerably thicker than the Me 262's, one factor in the latter's higher speed. Photo credited to Bureau of Aeronautics, Navy Division, dated 16 February 1945. (National Archives, Photographic Division, Box 2046, Number 33566)

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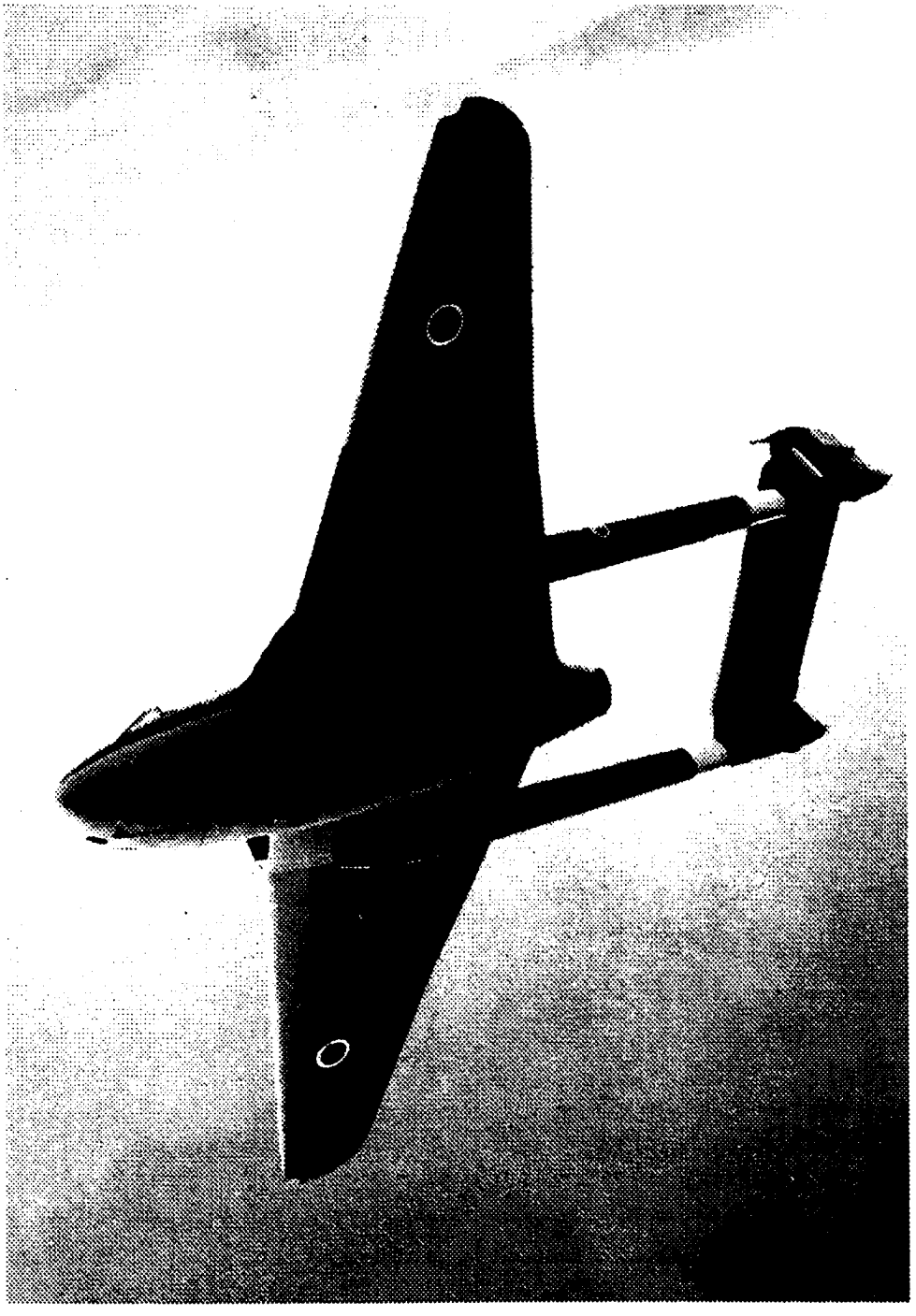
British De Haviland Vampire jet fighter. This version is the Sea Vampire, adapted for operations aboard aircraft carriers. The twin boom tail design is obvious. Photo dated 22 December 1950. (National Archives, Photographic Division, Box 2046, Number 33661)

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The Vampire from the side. The wingroot intake for the jet engine can be seen below the cockpit, and the exhaust outlet at the end of the fuselage, just below the tail booms. Photo credited to Aircraft and Engineering Section, Defense Air Branch, dated 1 December 1947. (National Archives, Photographic Division, Box 2047, Number 33753)

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A Vampire in flight. The graceful and unorthodox design can be fully appreciated in this view. Photo credited to Aircraft and Engineering Section, Defense Air Branch, dated 1 December 1947. (National Archives, Photographic Division, Box 2047, Number 33765)

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"It's nice to be first - but the money is in being second."
Bell Aircraft President Lawerence Bell[1]

Chapter 3
America Enters the Jet Age: The P-59 Airacomet

Although the first successful powered aircraft flight took place in the United States, and the Wright brothers taught Europe and the world to fly, it was Europe that soon took the lead in designing aircraft and advancing the limits of aircraft performance. After the Wright's initial flights, virtually all of the early flying records were established by Europeans flying European designed and built aircraft. When America entered the First World War in 1917, she possessed not a single combat-worthy aircraft, despite the massive air war that had been raging over Europe for several years. Lacking combat aircraft of its own, the United States Army was forced to equip its flying squadrons in Europe with planes designed and built in England and France.

During the First World War, both England and Germany had created independent air forces. That is, these air forces were not under the command of either the army or the navy, but rather were a separate, co-equal branch of the armed forces. In contrast, the United States placed its much smaller air force under the command of its army. It was originally the United States Army Air Service, then the Air Corps. Later this was changed to the United States Army Air Force. The American air force obtained separate, co-equal status in 1947, and became simply the United States Air Force. Until 1947, the American air force, and everything and everyone in it technically belonged to the United States Army. To avoid confusion, the term Air Force will be used throughout this work, regardless of the time frame.

The First World War provided a strong impetus for growth for the American aviation

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industry, although much of that growth was in the realm of civil aviation. Despite the efforts of military visionaries like Colonel William Mitchell, who argued vigorously for a large and independent American air force, American military aviation remained a largely neglected and under-funded field through the 1920s. In the mid 1930s, alarmed by the growth of large modern air forces in countries like Nazi Germany and Fascist Italy, the American army began to order and acquire larger numbers of modern aircraft. Some of the designs produced by American aviation companies in the late 1930s and early 1940s, such as the Boeing B-17 Flying Fortress, the Lockheed P-38 Lightning, and the Chance-Vought F4U Corsair, would be among the most successful combat aircraft in the Second World War.

Although the United States rapidly closed the gap and in some cases took the lead in the design and production of conventional combat aircraft, the status of jet propulsion was much less favorable. A number of theoretical studies about the benefit of gas propulsion for aircraft had been conducted in the United States, both by the military and private industry, beginning during the decade of the Wright's first flight. Sanford Moss examined theoretical and experimental gas turbines for his doctoral dissertation in 1903. Wright Field (the Air Force's technology research facility) produced a paper in 1936 entitled "The Gas Turbine as a Prime Mover for Aircraft." General Electric produced a study for Wright Field in 1937 entitled "Gas Turbine Power Plants for Aeronautical Applications." In 1939 GE produced a study on the subject of "Jet Propulsion Gas Turbines." Dale D. Streid, also at GE, wrote a memo in 1939 about "Airplane Propulsion by Means of a Jet Reaction and Gas Turbine Power Plant."[2]

Despite this, no effort had been made to actually test any of these theories or build jet engines, even on a small scale. More remarkably, little or no attention was paid to foreign

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developments in the field. While much of the German work on jet propulsion was done in secret, Flying Officer Whittle had patented his engine in 1930 and since 1935 had been working publicly on developing a functional jet engine. Despite this, both American industry and the military remained essentially ignorant of these innovations. However, since much of this sort of knowledge sharing was done via official government channels, and Whittle's work was generally ridiculed, mocked and ignored by British officialdom, it is perhaps not surprising that information on his work did not find its way to America in its early stages.

American scientists and engineers were working on various theories of jet propulsion, and by 1940 a number of companies had begun designing various axial flow jet engines. Allis Chalmers proposed a ducted fan engine (adding an extra fan to push more air into the compressor), Westinghouse was working on a basic jet engine, and GE was developing a turboprop (using a gas turbine to drive a propeller, with some of the exhaust gases adding velocity).[3] This work was almost entirely swept aside by the urgency of rearming America's woefully unprepared military forces for a conflict with Germany.

At least one American aircraft designer, the multi-talented Clarence "Kelly" Johnson, Chief Research Engineer for Lockheed Aircraft Corporation, had conducted independent studies into jet propulsion. By 1940 Lockheed had produced designs for their own jet engine and a strikingly radical airframe to house it. The engine, designated the L-1000 (an internal corporate designation), incorporated such advanced features as high compression ratio, twin-spool turbines and afterburners. The airframe was designated L-133, and was a radical canard design. That is, the wings were in the rear of the plane, and the moveable control surfaces (the canard) were in the front, reversing the usual placement. The plane was also to be made of stainless steel instead of

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aluminum, to better resist the high temperatures of high speed flight. The anticipated performance of the plane would have exceeded anything in the sky for almost ten years, until after the Korean War. However, the design was almost certainly too complex to make an effective combat aircraft. Moreover, the lengthy development time (4+ years) and the official United States government policy of forbidding the same company to produce both the airframe and engine for an aircraft killed the project. Lockheed was also officially strongly encouraged to concentrate on manufacturing its existing designs - the Hudson patrol bomber, a modified civilian airliner, and the P-38 Lightning, a twin-engined fighter - which were considered vital to the upcoming war effort.[4]

This was the state of the American jet fighter program when the Army Air Forces commanding officer, General Henry J. "Hap" Arnold, visited England in April 1941. While there, he was informed of the E.28/39 project, and given the opportunity to inspect the aircraft and the engine and to view several tests of the aircraft, including a short flight. Tremendously impressed with what he had seen, General Arnold discussed jet technology with a number of England's leading aviation officials, including Lord Beaverbrook, who oversaw all aircraft production. The result of these discussions was a tentative arrangement by which England agreed to provide information about the advances in jet propulsion, including full technological details, completed engines to study, and permission to manufacture the jet engines under licence. All of this was a huge time saver for the American aviation industry, allowing the companies to work with already tested technology, instead of having to reinvent it for themselves.

When General Arnold returned to the United States, he decided to put American efforts to produce a jet fighter into high gear. The choice of a company to design and produce this aircraft was a vexing one. Most American aviation companies were working round the clock to fill the

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government's orders for existing aircraft designs, and lacked the engineering staff and production facilities for designing such a new and unusual aircraft.

The choice of a company to study and produce the jet engines was also very important. On one point, General Arnold was inflexible - he would not allow the companies who produced conventional aircraft engines, such as Allison, Pratt & Whitney, and Wright, to work on jet engines. Although partially motivated by a desire to avoid interfering with their production of much-needed war material, General Arnold's decision was largely intended to avoid entrenched or fossilized thinking about new ideas, of the sort that had plagued Whittle's early work. Instead, he directed that the new jet engine be given to companies that had experience designing and building turbo-chargers for piston engines, as there was some similarity between these devices and jet engines. These companies included Allis Chalmers, Westinghouse, and General Electric. Of these, General Arnold chose the last, General Electric, based in Schenectady, New York, to produce America's first jet engine. At a meeting with GE officials, General Arnold presented the information on jet engines and told them "Gentlemen: I give you the Whittle Engine - consult all you wish and arrive at any decision you please - just as long as General Electric accepts a contract to build fifteen of them. "[5]

While the work on the all-important engine had been quickly allocated, the choice of a company to design and build the airframe of America's first jet plane remained. General Arnold decided to give the job to Bell Aircraft, based in Buffalo, New York. The proximity of Bell and GE's facilities was one factor in this decision. Other factors included Bell's small but innovative design staff, the fact that the company was currently producing only one military aircraft (the P-39 Airacobra, which was not widely used by the American Air Force), and the drive of Lawrence

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Bell, the company president, who met with General Arnold to request this opportunity for his company. His appeal was successful, and on 3 October 1941, Bell Aircraft was awarded a contract to design and build three XP-59A Airacomets.[6]

Unlike England's and Germany's first jets, which were unarmed test aircraft only, America's first jet was to be a fully functional fighter plane. This meant that it would have equipment such as guns and ammunition, armor plate and self-sealing rubber fuel tanks, all of which added a great deal of weight to the design. This created a serious challenge for the Bell team, as they were to design a fighter with superior performance that used a new and completely unknown type of power plant. Normally an aircraft designer has access to exhaustively detailed performance information on the power plant he is using for his design. Not only did the Bell team lack that information in this case, they did not even know what the engine looked like, having only vague outline drawings of the engine and rough estimates of its performance to work from.[7] To further complicate the design process, what was known about the jet engine's performance indicated that even with two of them the airplane would have insufficient engine power to achieve the speed and performance breakthrough they were striving for. Hoping for the best, Bell and his team went to work.

The project labored under extremely tight security. Only a handful of people at Bell and GE knew the full story of the work they were undertaking. In fact, the new jet aircraft's initial designation, the XP-59A, was part of that secrecy. The original XP-59 had been a piston-engined pusher propeller ground attack aircraft. A pusher propeller aircraft had the engine mounted facing the rear of the aircraft driving a propeller mounted behind it. The pusher style of engine design dates back to before the First World War, and a number of aircraft have combined both

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puller and pusher engine arrangements quite successfully. This aircraft had reached the stage of large mock-up but had progressed no further, due to lack of interest on the part of the Air Force.[8] The designation XP-59A was chosen for the new jet to make it appear as if this project was merely an extension of the old one. Security at Bell was also strict, with the employees who worked on the project using special facilities and essentially 'disappearing' from the company, to the surprise and curiosity of their co-workers.

GE's work on the Whittle engine was not without its difficulties. One major project that had to be completed before the company could even begin to plan the manufacturing of the engine was to completely convert the English measurements to American ones. Certain omissions and design problems in the drawings, which required correction, were discovered during this process, but the work proceeded at a brisk pace nonetheless.

Due to the relatively low power of the first generation of American jet engines, two of them would be required for power plants.[9] Even then the plane would be seriously underpowered. This was well known to the design team at Bell, but there was little that could be done about it. Although various models of the GE engines increased the power available for the P-59, even the most powerful of these had substantially less thrust than comparable British or German engines. This would turn out to be the Achilles Heel of the entire P-59 project.

The design the Bell team came up with for the airplane was fairly conventional, given the circumstances. Aside from a few features to optimize the plane for high altitude combat (oversized wing area and cockpit pressurization), the XP-59A used largely conventional features, many of them borrowed from Bell's earlier designs, the P-39 Airacobra and the P-63 Kingcobra. The XP-59A did incorporate low drag laminar flow wings.[10] The twin jet engines were to be

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located in the aircraft's fuselage, under the wings. These engines were housed in bulged nacelles which gave an almost pot-bellied look to an otherwise slender and graceful fuselage. The wings were mid-mounted well forward, straight with square tips. The high mounted tail surfaces were also rectangular in shape. The aircraft sat on tricycle landing gear. The pilot sat in a framed canopy above the forward edge of the wings. The plane's armament was to be concentrated in the nose of the aircraft, the most logical placement for a heavy concentration of firepower. The original XP-59A was designed to carry two 37 mm cannon with 44 rounds of ammunition each. Beginning with the tenth YP-59A, the armament was changed to three .50 caliber machine guns with 200 rounds each, and one 37 mm cannon with 45 rounds.[11]

The design of the XP-59A followed conventional aircraft construction techniques, which would later result in some minor problems with the actual aircraft. Although the major surfaces of combat aircraft were made of stressed aluminum at this time, the control surfaces (ailerons, elevators, rudders) were usually fabric covered. This rendered these surfaces more vulnerable to damage at high speeds, and also led to an unanticipated problem with the P-59. As the twin engines of the P-59 were mounted in the fuselage, this meant that the exhaust stream passed directly beneath the rear fuselage and tail of the plane. Jet planes often experience what are termed "hot" starts, where a quantity of jet fuel (mostly kerosene) collects in the tailpipe of the exhaust system. This fuel then ignites during engine start up, producing a long tongue of flame stretching from the rear of the engines. This phenomenon led a dubious onlooker to remark during a test of the P-59 "all I see is a six foot flame....what is it, flame powered?" [12] This is largely harmless to the aircraft itself, although not to any ground crew who have the misfortune to be in the vicinity. Fabric-covered surfaces, on the other hand, are very vulnerable to fire damage.

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Instances of P-59's setting fire to their own elevators were not unknown, and led to the practice of keeping the elevators angled as far up as possible during engine starts.[13]

Work on the P-59 proceeded with deliberate speed. The most significant delays to the project were those involving the engine manufacture. Similar problems seem to have affected most early jet fighter designs, whatever their national origin. Work on the first P-59 airframe was largely complete by the summer of 1942. In August 1942 America's first two production jet engines arrived at the Bell plant and were installed in the airframe. The Airacomet was ready for testing.[14]

The site selected for flight testing of America's first jet fighter was in many ways ideal for such activities. This was the Army Air Force Muroc Bombing and Gunnery Range, located on Muroc Dry Lake and Rogers Dry Lake, in California. Located in the heart of the Mojave Desert, not only was the site isolated and very secure, but the large, hard and flat dry lakebed made an ideal surface from which to fly and land. The name of the site, Muroc, had been given to it by the original homesteader on the land, Clifford Corum, in 1910. He had attempted to name a store he and his wife had built there the Corum Mercantile Company. When told by the state of California that this particular name was already in use, he simply reversed the spelling of his last name and the store became the Muroc Mercantile Company. The name was distinctive and it stuck. Of course, this site was an impressive distance from Bell's facilities in Buffalo, requiring disassembly of the aircraft which was then crated and shipped via railroad.[15]

This transit was not without difficulties. In order to prevent the engine bearings from seizing up during the extended transit, it was necessary to have the engines slowly rotated (using compressed air to move the engine components, as if they were operating). During extended

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periods of inactivity, the lubricants that reduce the friction on moving parts in an engine will drain to the bottom, allowing the bare metal parts to touch. These unlubricated parts can then "seize up" from friction, resulting in damage to, or the destruction of, the engine. This meant that a crew had to accompany the crated components during the trip. This six-day odyssey, as recounted by crew member Ted Rogers of GE, was worthy of a Keystone Cops or Three Stooges episode.[16]

The initial loading of the crates and the test of the compressor to rotate the engine proved successful, and the early stages of the journey uneventful, if trying to hold and tie down a one ton air compressor on a bumpy freight car at 60 mph can be termed uneventful. The second day of the journey saw the bearings of one of the freight car's wheel truck burn out, requiring the complete replacement of the assembly. This was done quickly and efficiently. At a stop that night, loud noises and jolts woke the team. When the car door opened and several armed men got on board, the initial reaction of the team was that saboteurs were trying to hijack the top secret airplane. Fortunately, that initial conclusion proved wrong, but the reality was almost worse. A carload of high explosives had been attached in front of their car, and a squad of Marines accompanying it had decided that the passenger car the team was riding in was going to provide them with accommodations. Some hurried negotiations with the Marines produced an armed truce, with the Marines and the team occupying separate ends of the car.

In Kansas City, the cars on the train were repositioned. This involved the use of a "hump," an elevated section of track used to give an unpowered freight car the momentum to roll down the desired track spur, crashing it into the rear of whichever train it was to join. After the Marine's explosives, in a freight car labeled "High Explosives - Do Not Hump," and coupled to

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one of the airplane component's car, was subjected to this procedure, the team convinced the railroad to place the explosives car at the end of train. But their trials were far from over. Sprinting to a nearby restaurant to order a hot meal to go, the crew returned to find no sign of their airplane. It took a search of the entire freight yard, aided by a skeptical yard policeman, to locate the car and return it to the proper train.

Under way once more, the compressor, which had just been refilled with gas, quit. Frantic checking revealed no obvious problems. Manipulating the choke managed to restart the compressor just as the jet engines were about to come to a halt. No sooner had the air pressure returned to normal than the compressor quit again. This time the problem was located. It was a clogged fuel filter on the compressor, which was blown clear. Dirty gasoline was the culprit. Although new, clean gas was used from another fuel drum, for the rest of the trip the compressor was quirky, running fitfully and threatening to give up.

Several days later, at a water stop in New Mexico, the team again ran to a restaurant for hot food. One of the team, Frank Burnham, did not make it back before the train pulled out, and was left behind. A bit further on, the freight train pulled off on a siding to repair a car. While sitting there, a passenger train passed by on the main line. The passenger train slowed as it passed, and Burnham jumped off it and rejoined his friends. However, they then sat there for several more hours, as repair efforts continued. The team finally telegraphed Wright Field to protest the delay, and the damaged car was cut out of the train and they proceeded westward.

No further incidents marred the final day of the journey. Crossing Arizona into California, the team and the aircraft finally arrived at San Bernardino and then took the spur to Muroc. As Ted Rogers put it: "We were saddle sore and filthy as we climbed down from the first coast-to-

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coast "flight" of a jet airplane -- six full days."[17]

Before continuing with the account of the testing of the P-59, a brief description of the occasionally confusing system of aircraft designation used by the Air Force is in order. The system of nomenclature authorized by the United States Army Air Force at that time used a combination of a letters and numbers to designate different types of aircraft. "B" meant Bomber, "A" meant Attack (tactical ground attack), "O" meant Observation, "F" meant Fotographic (reconnaissance), and "P" meant Pursuit (fighter) The admittedly confusing juxtaposition of the latter two designators goes back to 1924, when a simplified designation system was introduced by the Army. The Pursuit designation was the original label for fighters in the First World War, as they "pursued" enemy aircraft. At the time the system was introduced, there were no photo reconnaissance aircraft. The confusion was finally corrected in 1948, when all fighters were given the "F" designation, and, when necessary added an "R" for reconnaissance: RF-101, for example.

The numbers assigned were sequential, with each type of aircraft (fighter, bomber, etc.) having its own series. The higher the number, the more recent the design. Examples of this nomenclature include the B-17 Flying Fortress, A-26 Invader and P-51 Mustang. Although aircraft were also given specific names, these were never the "official" designation. As significant improvements or changes were made to the aircraft, they were indicated by adding a letter (in alphabetic order) following the numbers. Examples of this would be the B-17C, B-17D, B-17E, B-17F and B-17G models of the Flying Fortress and the P-51A, P-51B, P-51C and P-51D models of the Mustang. If minor improvements were made, insufficient to justify a new letter designation, they would be indicated by a hyphenated number added after the letter. An example of this would be the various models of Republic's P-47 Thunderbolt, such as the P-47D-25, P-

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47D-30 and P-47D-40.

During the design process, additional letters in front of the designation indicated the plane's status. An "X" before the designation indicated an experimental prototype, while a "Y" indicated a more advanced, pre-production prototype of the plane. "X" models were built to provide basic flight testing. "Y" models were built to test whatever changes and improvements were to be added to an "X" plane, and to determine the plane's suitability for mass production.

Upon arrival at Muroc in late September 1942, the XP-59A was assembled and began an extensive series of tests. Two additional XP-59A's eventually joined the original aircraft, the first arriving at the end of December 1942 and the second in early January 1943. Both of these aircraft arrived without engines, due to delays in engine production at GE. Six YP-59A's, which incorporated numerous minor design changes, were also eventually were shipped to Muroc for testing. Two of the YP-59A's were delivered in June 1943, two in October 1943 and two in November 1943.[18]

Upon arrival at Muroc, the aircraft were assembled, and various minor modifications were performed on them. They then underwent a series of immobile, or "static" tests, to ensure that all the systems, especially the engines, functioned properly. The aircraft then graduated to taxi tests, where the engines were used to move them on the ground, without attempting to take off. Finally, they graduated to actual flight tests. The first of these tests simply ensured that the aircraft could take off and land without problems. Even these simple tests were not without danger. The first flight of the second XP-59A was very nearly its last. This aircraft, XP-59A number 27-2, took off on its initial flight test on 15 February 1943, piloted by Frank Kelly. No sooner had the aircraft left the ground than the cockpit defroster malfunctioned, filling the cockpit

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with dense white smoke. Kelly displayed the cool decisiveness required of a test pilot, and immediately brought the plane around, cut power to the engines, and made a perfect "dead stick" landing.[19] In this case, the damage was minor and quickly repaired.

Not only did the various P-59 prototypes at Muroc experience the usual quota of various minor problems and "glitches" that are inevitable with any new aircraft, but the jet engines proved to be extremely troublesome. The untried and unfamiliar technology of the jet engines meant that everyone involved in the testing process had to learn a new set of rules. This included such apparently common sense concepts as not getting too close to the exhaust stream of an operating jet engine.

> "On this date [20 February 1944], Bell Inspector E.F. Fisher, weighing 200 pounds, walked into the jet approximately four feet behind the nozzle while the aircraft was operating at rated power. It lifted him approximately 3 feet in the air, tumbled him end over end approximately 3 times, and he made a face-down landing on the concrete approximately 25 feet behind the nozzle exit. No substantial injuries were sustained other than brush burns obtained upon contact with the concrete surface."[20]

The engines were also somewhat quirky and temperamental, requiring a great deal of maintenance. One fairly serious problem with the engines was known as "surge." Jet engine surge was produced by uneven air compression, which resulted in irregular fuel combustion. This led to fluctuations in the thrust produced by the engine, hence the term "surge". This problem was especially noticeable at high altitudes. The problem was eventually corrected by modifications in the compressor and turbine design in later models of the jet engines. Unfortunately, this was of no help at all for the P-59. The early GE jet engines also had an extremely short life - about ten hours of operation before replacement was necessary.[21] All of

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these factors combined to stretch the testing program for the P-59 to almost a year and a half. The experimental tests on the X and YP-59A's lasted from 1 October 1942 (the first jet flight in America) to 27 February 1944.[22] Since the war effort demanded urgency, this delay in the test cycle would prove damaging to the P-59 program.

Very high levels of secrecy and security were attached to the P-59 tests. The relative isolation of the Muroc facility was a major factor in maintaining this secrecy. The virtual quarantine of the test crew in primitive facilities was another. Some of these security measures tended towards the absurd. One of the more unusual was the manufacture of a large, four-bladed, fake propeller for the XP-59A. When the aircraft was being moved in the open where civilians might see it, the fuselage was covered by canvas tarpaulins, and the fake propeller was attached to the nose, to give the impression of a conventional piston-engined aircraft (although why a piston-engined aircraft would have to hide under tarpaulins was never explained). This incident occurred on 10 March 1943, during the relocation of two of the XP-59A prototypes. Due to heavy rain, Muroc was unsuitable for flying, and the aircraft were towed down a highway to Hawes Field, about 35 miles away. The propeller was built by Joe Brown, one of the test crew.[23]

On at least one occasion, the demand for secrecy had near fatal consequences. On 24 September 1943 an XP-59A was flying, with a conventional piston-engined aircraft along to photograph the flight. During the flight, the weather abruptly shifted. Skies that had been clear and calm during take-off were suddenly filled with a raging sandstorm. The photo plane broke away to fly to Burbank to escape the storm. The XP-59A, however, was forbidden to land at such a public facility for security reasons. Like most other early jets, the P-59 consumed fuel at a prodigious rate. The P-59B, for example, carried a maximum of 290 gallons of fuel internally,

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which sufficed for a combat range (out and back) of only 400 miles, while the long-ranged and fuel thrifty P-51 Mustang carried only 269 gallons of internal fuel, but had a combat range of 950 miles.[24] Since the XP-59A was running low on fuel, it was forced to attempt a landing at Muroc in the teeth of the storm, with zero visibility.[25] Demonstrating again why test pilots are among the very best in their profession, Jack Woolams made a perfect landing using only his instruments for reference.

During these extensive tests, the P-59 demonstrated generally acceptable and even pleasant handling characteristics. In particular, the YP-59A demonstrated excellent unpowered stability and flight characteristics, to the point where test pilots often deliberately flew until the plane ran out of fuel, then landed the plane "deadstick," or powerless. The one major problem with the YP-59A's flight characteristics was a crucial one, however - "directional instability at high speeds," meaning the nose of the aircraft slid from side to side at high speeds (technically referred to as yaw). This characteristic gave the P-59 unsatisfactory performance as a gun platform. In simple language, at high speeds, the pilot would be unable to hit a target with the guns. This defect rendered the P-59 useless as a fighter.[26]

Unfortunately, due to the lack of power of its engines, it also revealed disappointing performance statistics. The top speed of the P-59 was only 409 mph, which was actually slower than a number of existing piston-engined fighters. In contrast, England's Gloster Meteor could reach 490 mph, and Germany's Me 262 540 mph.[27] The P-59 was flown in a number of combat simulations tests against several of America's best piston-engined fighters, and was outclassed in almost every test category. Larry Bell's apprehensions about designing a jet fighter with underpowered engines had been proven correct.

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Largely as a result of these tests, and encouraged by the prospect of superior performance from Lockheed's rival design, the XP-80, the Air Force canceled the P-59 project. After the construction of the prototype, Bell had asked for a contract to produce 300 P-59's. After consideration, including the production loss of approximately 600 Bell P-63 Kingcobra fighters if this contract was awarded, the Army had instead contracted for 100 P-59s. Bell had begun building these airplanes during the extended tests of the prototypes at Muroc and had completed 20 examples of the P-59A (essentially the YP-59A). It was decided to add additional fuel tanks to the aircraft, beginning with the 21st aircraft. These modified planes were known as the P-59B-1. The Air Force wished to cancel production after the 39th aircraft, but Bell persuaded them to terminate production after the 50th plane had been finished.[28]

Most of the production P-59's were delivered to the United States Army Air Force and assigned to the 412th Fighter Group, where they were used as jet transition trainers, to introduce pilots to the principles of jet powered flight. The 412th Fighter Group, consisting of the 29th, 31st and 445th Fighter Squadrons, with some of America's foremost fighter pilots (many of them aces, including such well-known pilots as Don Gentile and eventually America's "ace of aces", Richard Bong) was formed in November 1943 as part of the 4th Air Force, Southwest Command, Depertment of the Interior (Pentagonese for the continental United States). The 412th was formed for the specific purpose of introducing jet fighters into operational service. They were the only Air Force unit to be equipped with P-59's, although individual aircraft were sent to other bases and commands to introduce American pilots to jet aircraft. When the P-59 was deemed unsuitable for combat, the 412th was then designated as the first American unit to receive the P-80 Shooting Star, America's second jet fighter.[29]

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P-59s proved successful in the role of jet transition trainer, although they were quickly phased out of the Air Force's inventory as later jet aircraft such as the P-80 became available. However, two YP-59A's and three P-59B-1's were delivered to the US Navy for testing at their Patuxent River, Maryland facility.[30] A further YP-59A was given to England for testing. This aircraft was put through a series of tests, and apparently did not impress the Royal Air Force any more than it had the United States Army Air Force, for after completing the testing it was returned to Wright Field in Ohio.[31]

This was not quite the end of the P-59 program. There were two additional attempts by Bell to produce an effective jet fighter. The original XP-59A design team, frustrated by the power limitations of the engines they had to work with, dreamed of being able to design a plane using the next generation of more powerful jet engines. The result of this was the XP-59B. Although the designation of the project was very similar (it was adopted by the company as a bureaucratic camouflage measure, to make the project seem an extension of the XP-59A), the aircraft design was quite different. The XP-59B was to have only a single engine, producing 3,000 to 4,000 lbs of thrust (compared to the 1,250 lbs of thrust of the early XP-59A engines). The XP-59B was to have the engine housed in the fuselage, with air intakes in the leading edges of the wing roots. The goal was a fighter that could reach 600 mph. Begun in the winter of 1942 after preliminary flight tests of the XP-59A proved disappointing, the project had advanced to the point of construction of a wind tunnel model. In the summer of 1943 it was abruptly canceled, and Bell was ordered by the Air Force to turn over all plans and research information to Lockheed, to aid them in their XP-80 project. The cancellation was a strong blow to the design team, who believed they were on track to producing what everyone connected with the jet fighter program wanted - a

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real hot rod.[32]

The second of these attempts to continue the P-59 project took a different approach. Instead of a totally new design, such as the XP-59B, this project, designated the XP-83, simply scaled up the P-59. Known informally as the P-59's "Big Brother," the XP-83 was intended to be a long-range bomber escort. Unlike the XP-59B, two XP-83 prototypes were actually built. Using two GE J-33 jet engines, each producing 3,750 lbs of thrust, the XP-83 was able to reach 522 mph. It was, however, a large and rather clumsy plane. By the time these prototypes were completed (the fall of 1944), the war was obviously nearing an end, and the earlier urgency for jet fighters had receded. With other promising jet fighters, such as the P-80, becoming available, the XP-83 project was canceled.[33]

Although the Bell P-59 did not turn out to be a useful combat aircraft, it was still an important and historic design. It was the very first jet-powered airplane produced in the United States. The attempt to make our first jet plane a high-performance fighter imposed great difficulties on Bell's design team. Even more limiting was the lack of a sufficiently powerful engine. Both England's and Germany's first combat-capable jet fighters were designed with two engines, each producing close to 2,000 lbs of thrust. The P-59 was forced to try to duplicate their success with engines of only 1,200 lbs of thrust (1,600 lbs in later models). This lack of power meant that no matter how brilliant the Bell design team, the laws of physics would conspire to limit what they could accomplish. That the P-59 proved as effective as it did under these limitations is a tribute to the inventiveness and hard work of the Bell design and production staff.

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1. Bell Aircraft President and founder Lawrence Bell, commenting on his company's efforts building the P-59 jet fighter. David M. Carpenter, ***Flame Powered: The Bell XP-59A Airacomet and the General Electric I-A Engine - The Story of America's First Jet-Powered Aircraft*** Jet Pioneers of America, 1992, p. 4.

2. Carpenter, ***Flame Powered***, pp. 6-7.

3. Carpenter, ***Flame Powered***, p. 9.

4. Steve Pace ***Lockheed Skunk Works*** Osceola, WI: Motorbooks International, 1992, pp. 31-38.

5. Carpenter, ***Flame Powered***, p. 12.

6. "CPFF Contract W535 ac-21931, entered into with Bell on the 30th, Sept. 1941, for three XP-59A airplanes, one wind tunnel model, and data, was approved by the Under Secretary of War on 3 Oct. 1941 in the amount of $1,551,350 plus a fixed fee of $93,081, making a total cost of $1,644,431" Document Abstracts, from the ***Case History of the P-59***, prepared by the Historical Office, Wright Field. Catalog Number 202.1-38, microfilm collection of the Office of Air Force History, Bolling Air Force Base, Washington, DC.

7. Carpenter, ***Flame Powered***, p. 20.

8. Carpenter, ***Flame Powered***, pp. 14-5.

9. Power output ranged from 1,250 lbs of thrust for the early Type I to 1,600 lbs of thrust for the Type I-16. Ibid., p. 50.

10. Ibid., pp. 19-23.

11. Carpenter, ***Flame Powered***, pp. 23-5, 76.

12. Carpenter ***Flame Powered***, p.4.

13. Ibid., pp. 24-5.

14. Ibid., p. 27.

15. Steve Pace ***Edwards Air Force Base: Experimental Flight Test Center*** Osceola, WI: Motorbooks International, 1994, p. 11.

16. The entire story of the trans-continental journey of the original XP-59A is told by Rogers in Carpenter, ***Flame Powered***, pp. 28-9.

17. Ibid., p. 29.

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18. Carpenter, ***Flame Powered***, pp. 39-40.

19. Ibid., p. 38.

20. Ibid., p. 43.

21. Ibid., p. 42.

22. Ibid., pp. 31, 48.

23. Ibid., pp. 40-1.

24. Lloyd S. Jones, ***U.S. Fighters*** Fallbrook CA: Aero Publishers, Inc., 1975, pp. 130, 154. Larry Davis, ***P-51D Walkaround*** Carrollton, TX: Squadron-Signal Publications, 1996, p.10.

25. Carpenter, ***Flame Powered***, p. 46.

26. Ibid., p. 40.

27. The speed of the P-59 can be found in a number of sources, including Alain J. Pelletier, ***Bell Aircraft Since 1935*** Annapolis, MD: Naval Institute Press, 1992, p. 54. The figures for the Me 262 and Meteor are taken from Ethell and Price, ***World War II Fighting Jets***, pp. 53, 106.

28. Carpenter, ***Flame Powered***, p. 51.

29. Carpenter, ***Flame Powered***, p. 52. David R. McLaren ***Lockheed P-80/F-80 Shooting Star: A Photo Chronicle*** Atglen, PA: Schiffer Military/Aviation History, 1996, pp. 17-18.

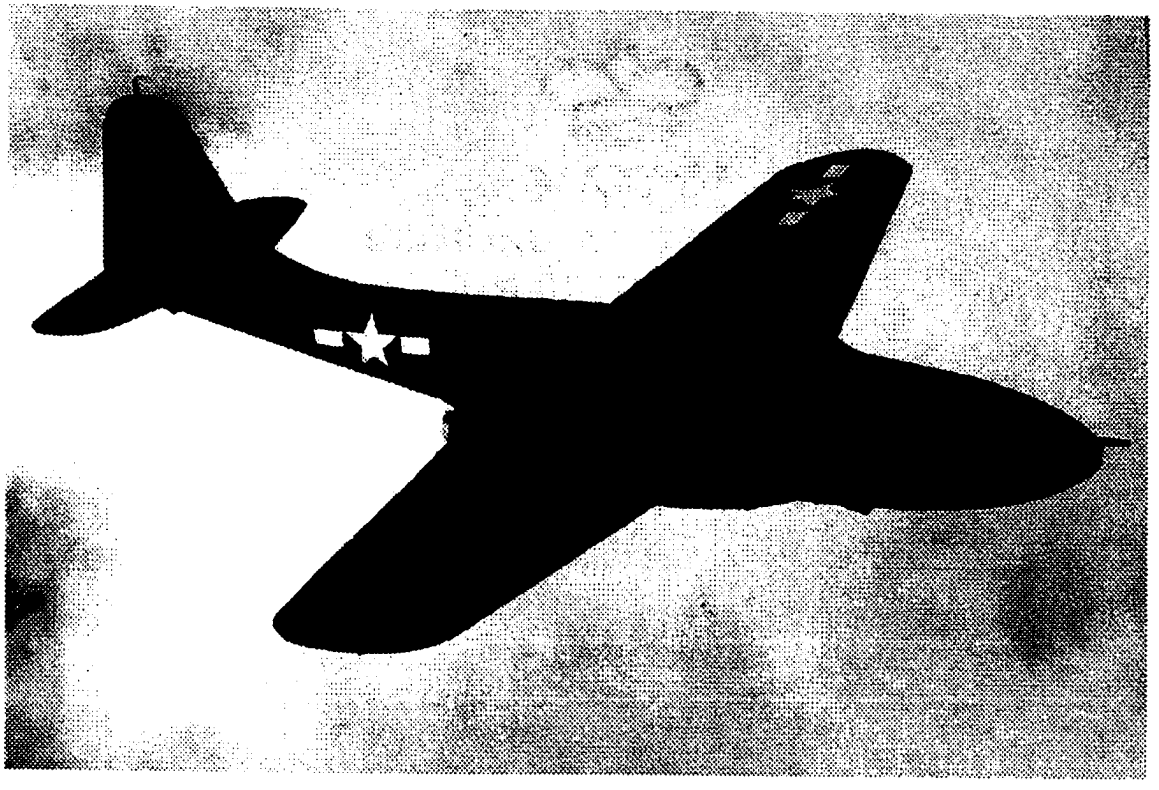
30. Carpenter, ***Flame Powered***, pp. 51-5.

31. Ibid., pp. 43-4.

32. Ibid., pp. 57-8.

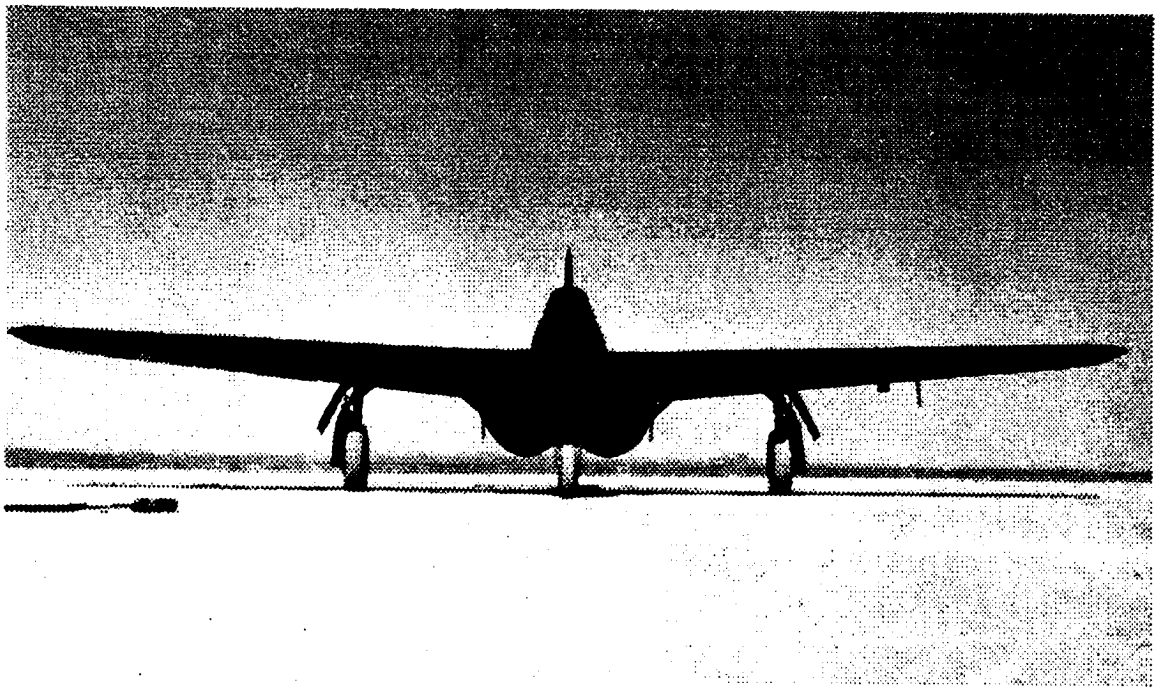
33. Ibid., p. 59.

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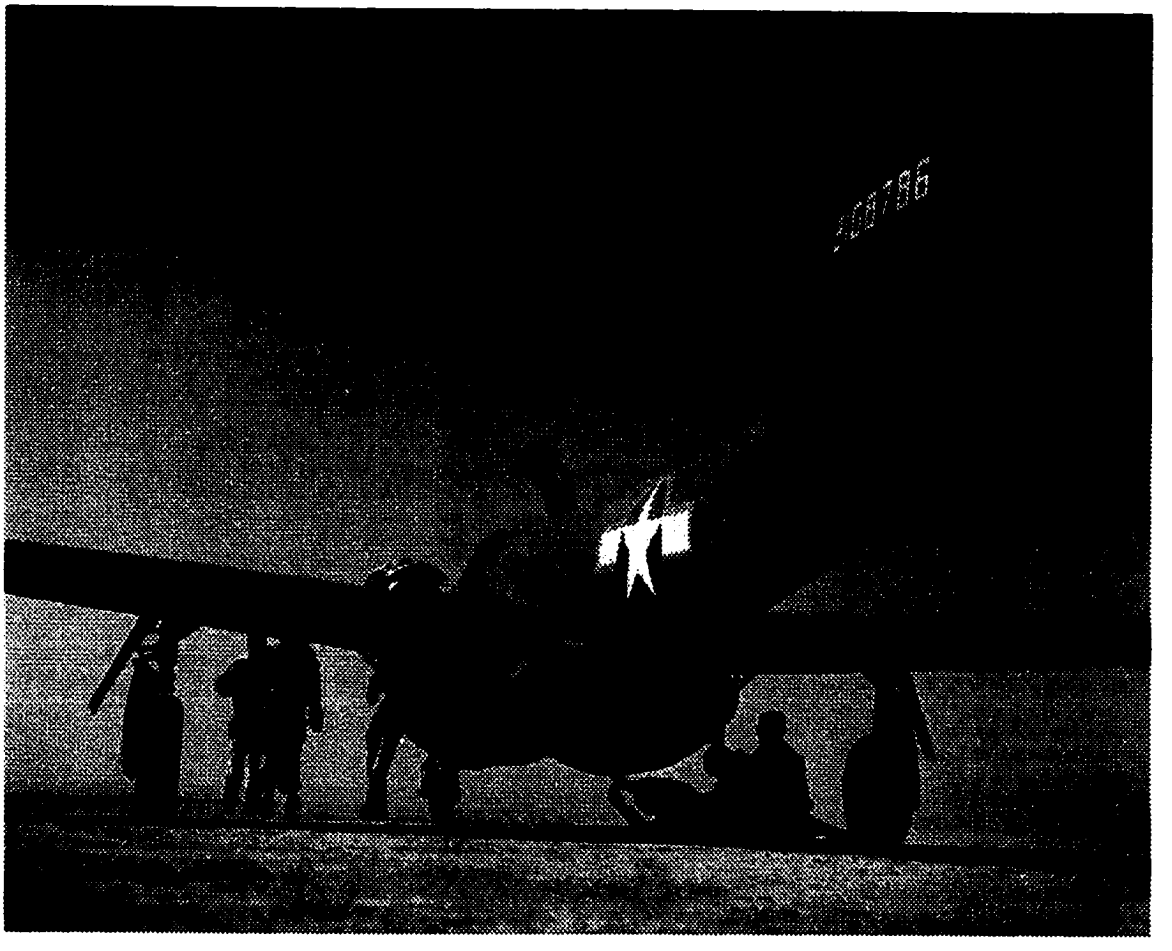
Bell XP-59A in flight. The plane wears the standard U.S. Army Air Forces camouflage of Olive Drab on the upper surfaces and Light Gray on the lower. The thick framing of the canopy can be seen in this photo. Several blast tubes from the plane's armament protrude from the nose. Photo credited to Captain MacAndrews, Bureau of Public Relations, dated 10 October 1944. (National Archives, Photographic Division, Box 2028, Number 29837)

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An XP-59A on the ground at Muroc. The aircraft itself was quite slender, but the two engines add a bulgy, pot-bellied look. Photo credited to Bell Press Release, dated 27 September 1944. Original caption reads "P-59A Airacomet - Jet Powered". (National Archives, Photographic Division, Box 2028, Number 29839)

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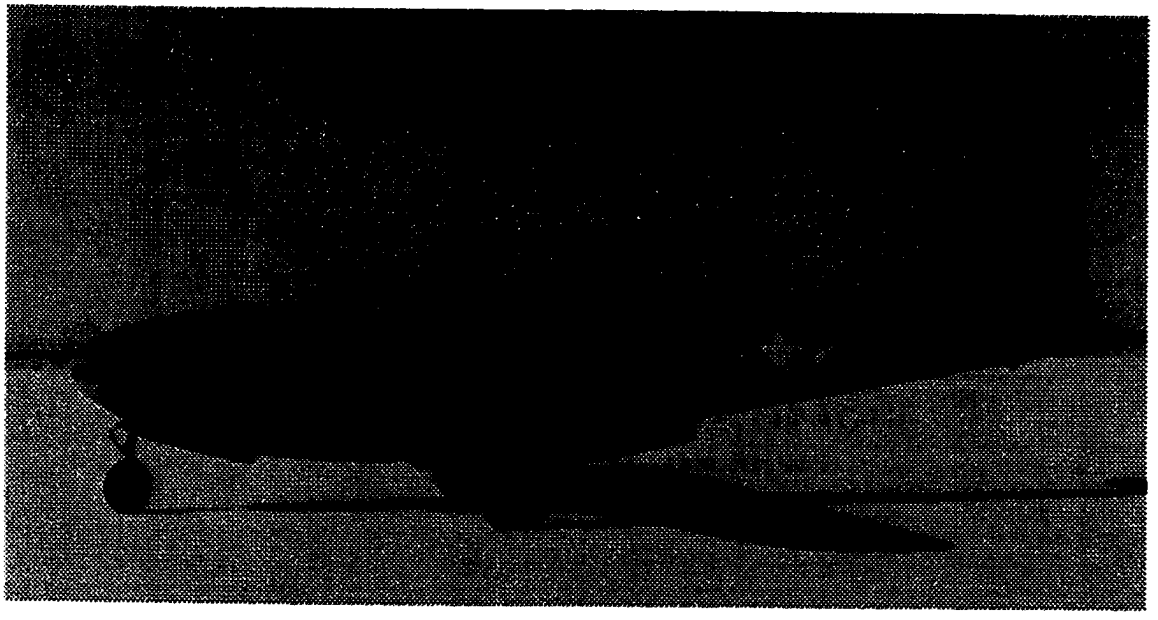
XP-59A being serviced at Muroc. Note that the aircraft wears the temporary red outline to the national insignia, used only between June and November 1943. Photo credited to Bell Press Release, dated 27 September 1944. (National Archives, Photographic Division, Box 2028, Number 29840)

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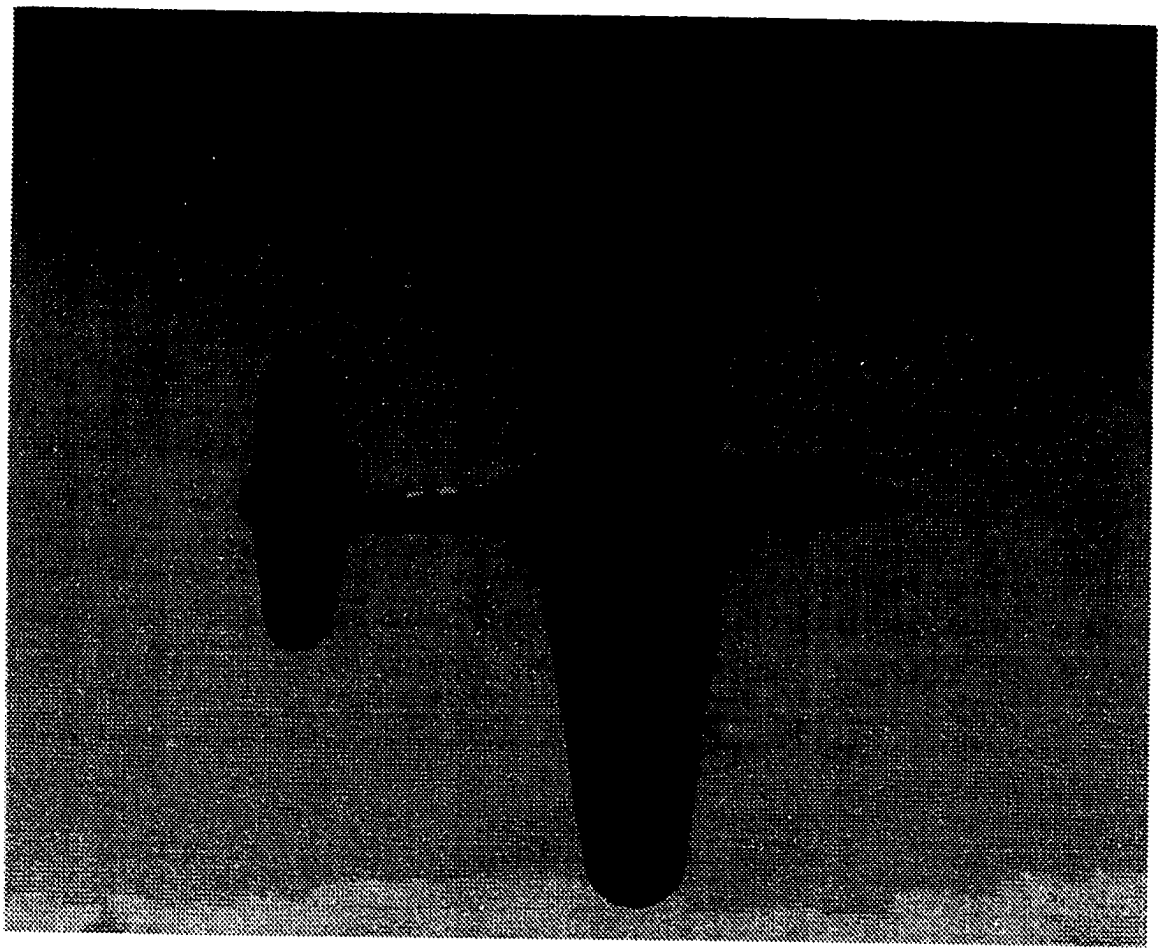
The XP-59A in flight, from the rear. The long wing span and large wing area, relative to the size of the plane, are notable in this picture. Photo credited to Bell Press Release, dated 27 September 1944. (National Archives, Photographic Division, Box 2028, Number 29841)

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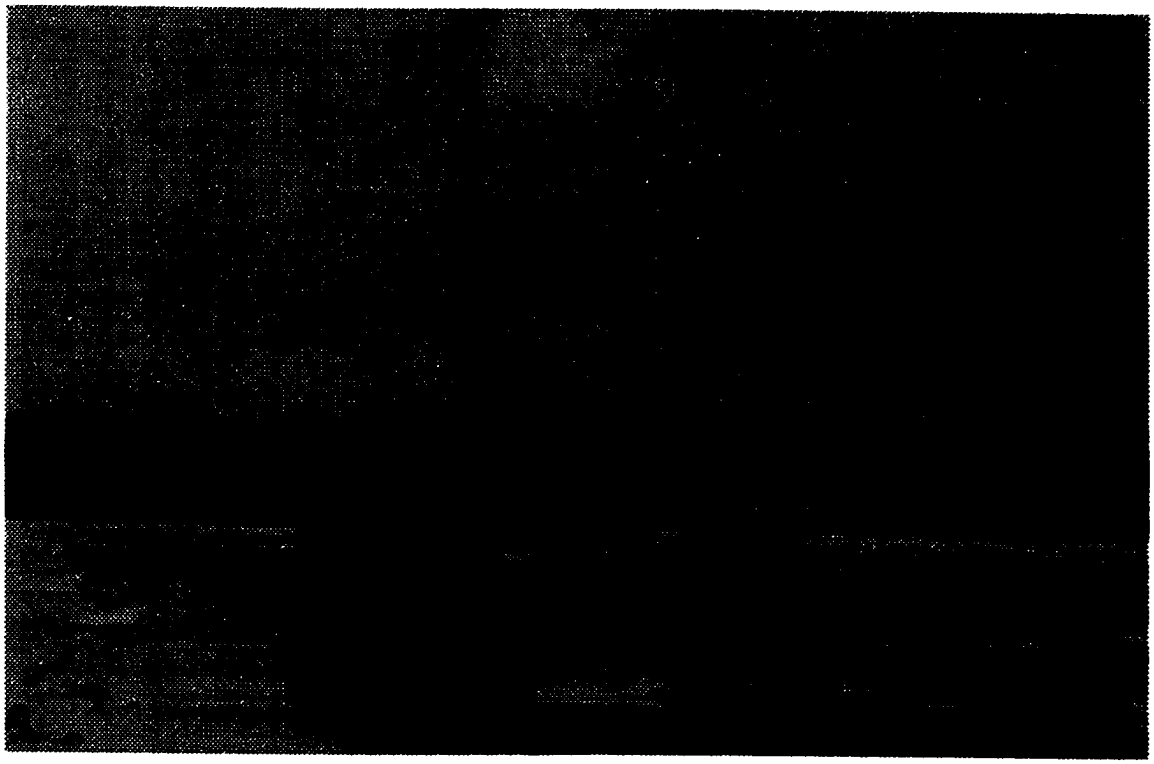
XP-59A on the ground at Muroc. The short and squat engine nacelles are obvious in this shot. Photo credited to Captain MacAndrews, Bureau of Public Relations, dated 10 October 1944. (National Archives, Photographic Division, Box 2028, Number 29843)

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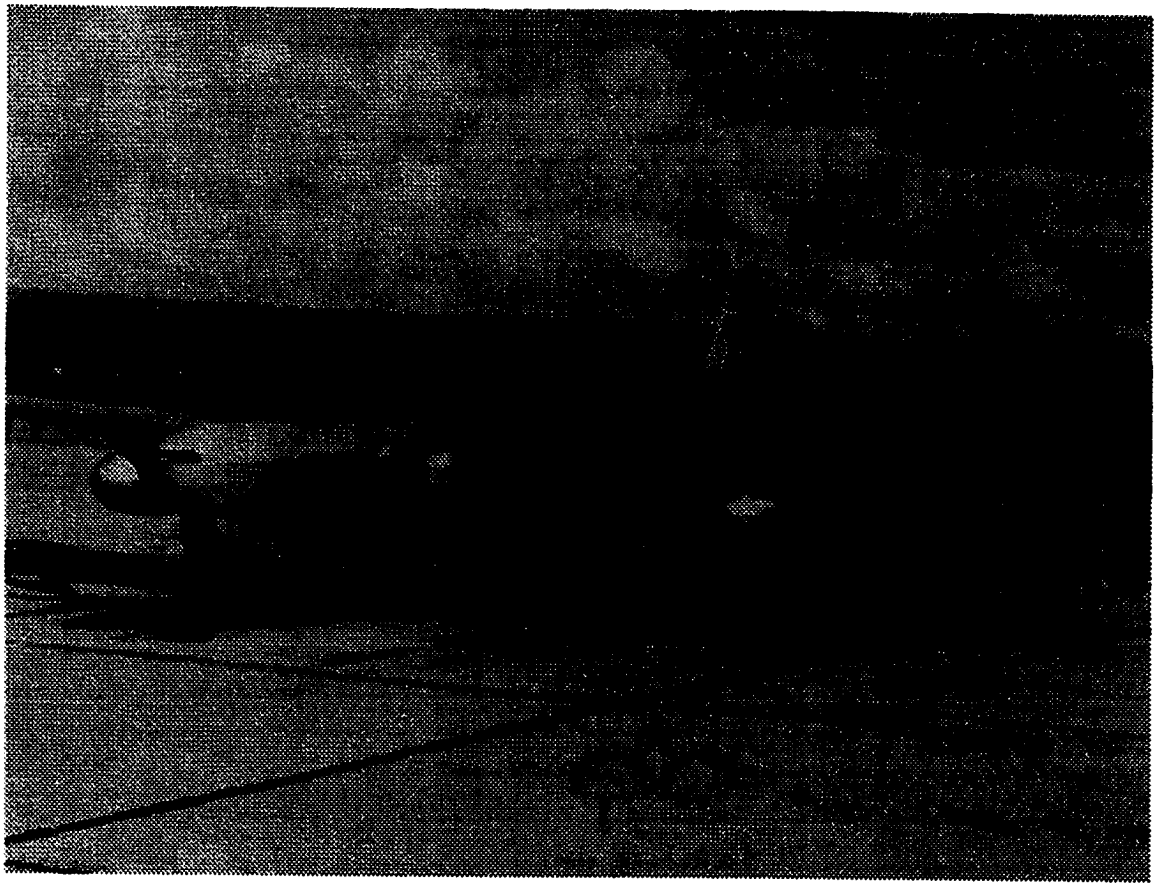
XP-59A in flight. The chunky engine nacelles are clearly visible. Photo credited to Captain MacAndrews, Bureau of Public Relations, dated 10 October 1944. (National Archives, Photographic Division, Box 2028, Number 29844)

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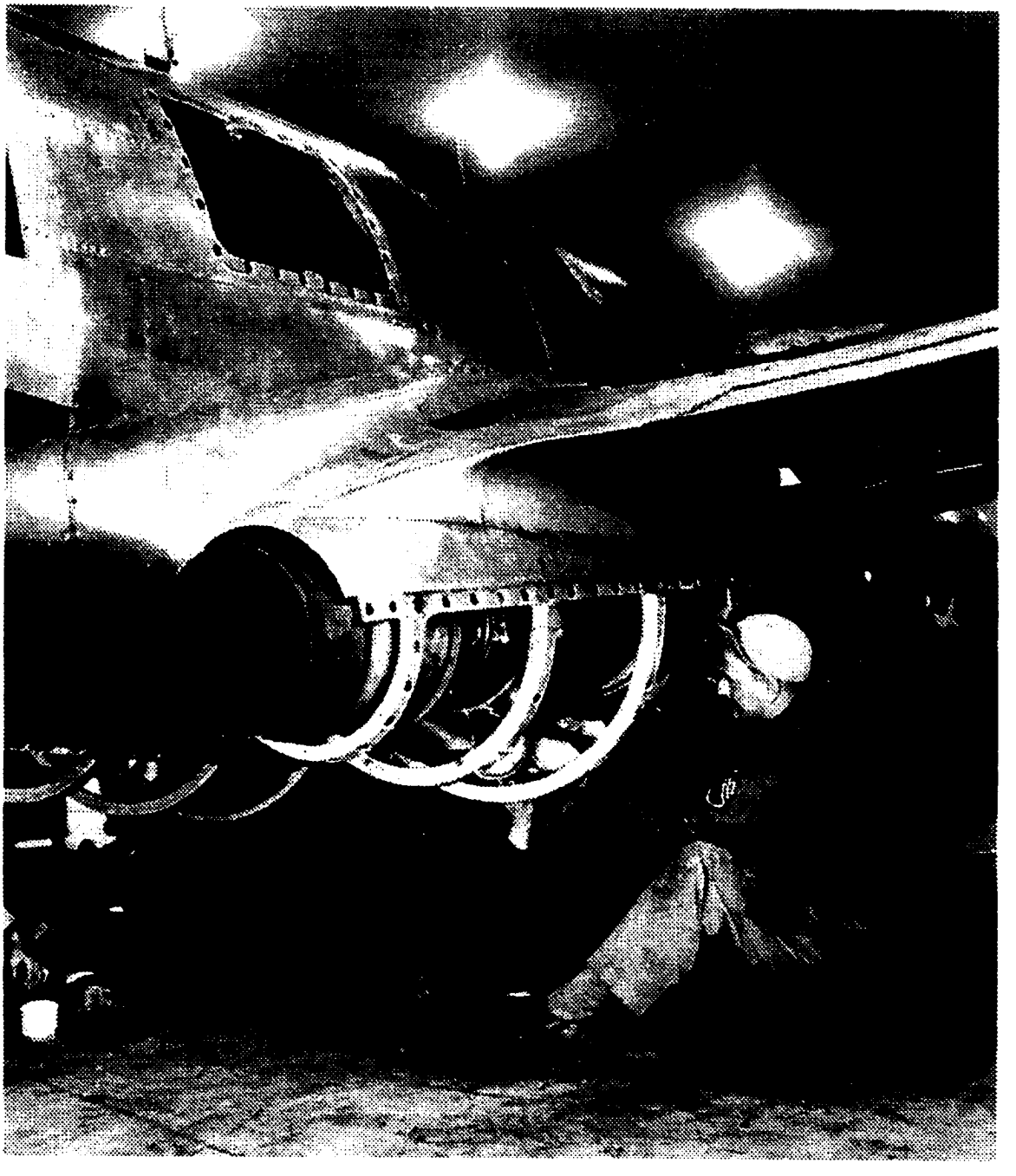
XP-59A on the ground. Photo credited to Captain MacAndrews, Bureau of Public Relations, dated 10 October 1944. (National Archives, Photographic Division, Box 2028, Number 29845)

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P-59B on the ground. Note the natural aluminum finish, and the external fuel tanks under the wings. The sliding canopy used on production versions, rather than the upward hinged type used on the prototypes, can also be seen in this shot. Photo credited to Chico Army Air Field, California, dated 28 May 1945. (National Archives, Photographic Division, Box 2028, Number 29860)

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Engine work and other maintenance being performed on a P-59B. Note how the lower panels completely remove for access to the engine. Photo is uncredited and undated. (National Archives, Photographic Division, Box 4002, Number 41182)

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"The recommendation was made that production of the...P-80A airplanes be expedited to the utmost because the P-80A should be the most successful defense against enemy jet airplanes as well as the most potent offensive fighter against any enemy aircraft or installations."
From test reports evaluating the P-80 vs. the P-51[1]

Chapter 4
America's First Combat Jet: The P-80 Shooting Star

America's first jet fighter, the P-59, was initiated because General Arnold discovered the English experimenting with a new type of aircraft propulsion system that America did not yet possess. America's jet fighter program was launched both because of the potential performance benefits of jet propulsion and the fear of being left behind in the development of a new technology. It is important to realize that America faced no recognized threat from enemy jet aircraft when the P-59 was designed.

Although the Me 262 project was initiated in 1938 and the aircraft first flew in 1941 (albeit powered by a conventional piston engine in the nose, as neither of the jet engines under development were available), delays and problems with the development of both the Jumo and BMW jet engines meant that the Me 262 did not make its first jet powered flight until 18 July 1942.[2] The P-59, while not initiated until the summer of 1941, first flew in October of 1942. When examined in this fashion, the American jet fighter program appeared to be proceeding nearly in parallel with the German one. Such appearances were rather deceptive, however.

In both cases, problems with the jet engine design and reliability plagued the plane's development cycle. There were, however, some fairly significant differences between the two projects. With the P-59, underpowered engines and a conservative design meant that it would never become a successful combat aircraft. The Me 262, in contrast, despite continued problems

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with the engines, was viewed by both Germans and Allies as a potential war-winner, a bold new design with outstanding performance and devastating firepower. So although the development of the two planes proceeded at a similar pace, the Me 262 represented by far the bigger threat. By the middle of 1943, two unpleasant facts were obvious to the American Air Force. The first was that although final comprehensive tests were many months off, preliminary tests indicated that the P-59 could not be considered a successful combat aircraft, as its performance could not even match that of conventional piston-engined aircraft. The second problem was that Germans were rapidly developing a jet fighter that had performance well in advance of anything else in the air. With the potential of the Me 262 to disrupt the growing Allied strategic bombing offensive, an American counter to the Me 262 was needed.

It was with this in mind that Air Force officials approached "Kelly" Johnson of Lockheed with the idea of designing a new jet fighter. Although the Air Force had officially rejected his earlier efforts to produce a jet fighter, the idea of designing a jet-powered aircraft had never been far from Johnson's mind. While Johnson was at Eglin Field in Florida in May 1943 to observe armament trials for another of his designs, the P-38 Lightning, he was approached by Air Force representatives and told that the Air Force would now be receptive to a design for a jet fighter, powered by the latest British jet engine. Johnson immediately set to work, sketching preliminary ideas on the flight back to California.[3]

Once back in Burbank, Johnson gathered a team of engineers and mechanics to flesh out his ideas. He demanded, and got, permission to recruit anyone he wanted for the project, and to isolate them from the rest of the company.[4] So confident was Johnson of Air Force approval that he began to proceed with the necessary work for fabrication of the prototype aircraft. This design

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received the corporate designation L-140.[5] For reasons of both secrecy and space, the L-140 project personnel had to be located in a very crude structure constructed of raw lumber, plywood and tarpaper next to the company's wind tunnel facility. From these humble beginnings grew the famous Lockheed "Skunk Works," headed for many years by Kelly Johnson himself, which produced a number of important and often top secret aircraft for the Air Force.

The term "Skunk Works" derived from a popular comic strip of the time, Al Capp's "Li'l Abner." In the strip, the tiny town of Dogpatch has a moonshine still. This establishment was highly secret, just like Lockheed's new jet project, and known, in Capp's idiosyncratic spelling, as the "Skonk Works." One of the engineers assigned to the project, Irving Culver, was a huge fan of the strip. He was assigned to answer the phones one day, and although aware of the need for guarding the secrecy of the project, realized he had no special procedure for doing so. So when the phone rang, he answered with "Culver, Skonk Works." Like many such unintentional nicknames, it stuck, despite Kelly Johnson's initial dislike.[6] In addition to the P-80, the Skunk Works also created the U-2 Dragon Lady and SR-71 Blackbird, high-speed, high-altitude photographic spy planes, the world's first mach 2 fighter, the F-104 Starfire, the tremendously versatile C-130 transport aircraft, the F-117A Stealth Fighter and the very recent F-22 Advanced Tactical Fighter.[7]

Kelly Johnson took his design to Wright Field during a three day Air Force conference there in June 1943. He and his team had done enough work to make a fairly detailed presentation to the Air Force, which was received quite positively.[8] Johnson's design promised to be simple and sturdy, and to have the outstanding performance the Air Force was looking for in a jet fighter. To further sweeten the deal, Johnson promised to have the flyable prototype finished within the

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almost unheard of time of 180 days.[9] The Air Force was impressed enough to ask Lockheed to construct a prototype for evaluation. The prototype was to be designated the XP-80, and the whole program was to be referred to as Secret Project MX-409.[10]

The XP-80 was to be powered by a British-built de Haviland Halford H-1B engine, which, in keeping with the idiosyncratic British custom of naming virtually every piece of military equipment, was known as the Goblin. The Goblin was rated at 3,000 lbs of thrust, and was to be obtained through the agreement reached with England regarding the sharing of jet engine technology. Although the original engine for the prototype was to be sent from England, the production engines would be license-built copies of the Goblin, designated the J36, built by the Allis-Chalmers company of Milwaukee, Wisconsin.[11] The prototype aircraft was to be equipped with six .50 caliber machine guns, self-sealing fuel tanks, armor protection for the pilot and tricycle landing gear. Lockheed would be paid $495,210 for costs plus a four percent fee for producing this prototype.[12]

Unlike the Me 262, the design of the XP-80 broke little new ground. Aside from the jet engine, few new concepts were attempted, in part because of the very demanding delivery schedule. Still, the XP-80 was a very clean and pleasant design. A laminar flow wing was mounted at the bottom of the cylindrical fuselage, at about the mid-point between the nose and tail. The laminar flow wing was designed to reduce drag and improve aircraft speed, and was the result of engineering studies by NACA and wind tunnel tests at Cal Tech Laboratory. Standard aircraft wings were largely flat on the bottom and curved on top. The curvature of the top section was such that, when looked at in cross section, the wing is thickest near the front, and then gradually tapers toward the rear. A laminar flow wing, in contrast, is curved on both top and

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bottom, and the thickest portion of the wing is almost two-thirds to the rear of the wing. This resulted in a substantially smoother airflow over the wing, reducing drag and allowing a higher top speed. The P-51 Mustang was the first American plane to use the laminar flow wing.[13]

The jet engine was to be mounted inside the fuselage about two-thirds of the distance back from the nose, at the center of gravity. A pair of air ducts located on the fuselage just forward of the wing roots allowed the necessary airflow to the engine. The armament was to be located in the bluntly rounded nose section, allowing for a very tight concentration of firepower. The pilot sat in a cockpit just forward of the wing, under a jetisonable bubble canopy that provided excellent visibility. A conventional rudder and tailplanes were located at the rear of the fuselage, just above the engine exhaust duct. The short main landing gear legs were mounted in the wings, with the nose wheel being located just to the rear of the nose-mounted machine guns and forward of the air intake ducts.

There were a few new or unusual features of the design. The most important of these was the design of the wing. Although the idea of sweeping back the wing was not considered, the importance of the wing design in high-speed flight was recognized. In the case of the XP-80, in addition to the laminar flow wing, another key factor was the variation in wing thickness, or cross-section. In order to achieve the best high-speed performance, the Lockheed team used a new ratio of wing thickness between the root (where the wing attaches to fuselage) and the tip. This ratio had been predicted by NACA (the National Advisory Committee on Aeronautics, the forerunner of NASA) to give optimal high-speed performance, especially near the critical mach limit, although it had never actually been tested. "Plans called for National Advisory Committee for Aeronautics (NACA) 65-series wing with a thickness taper from 13 percent at the root to 10

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percent at the tip, a design which, although not previously flight tested, was predicted to give excellent high-speed performance."[14]

Another unusual feature of the prototype was hydraulic assist for the ailerons and rudder, to aid in moving these control surfaces at high speeds.[15] Previously, almost all aircraft used simple mechanical linkages to move the control surfaces, which meant that quick manuvers at high speeds or in large aircraft frequently demanded enormous strength from the pilot to control the aircraft. The extremely high speeds at which the P-80 was to operate made it important to give the pilot some assistance in moving the controls.

Equally significant were the features that were omitted from this design. Intended to operate only at short ranges in the daytime, the XP-80 lacked instruments for long-range or poor visibility conditions and lighting for the cockpit and instruments. Despite being designed to operate at high altitudes, there was no provision for cockpit pressurization. Although a cockpit heating system was installed, the possible need for a cooling system was overlooked. The plane also lacked pilot controlled trim tabs for the ailerons and rudders, relying instead on tabs set manually on the ground prior to take-off. During the course of the testing of the XP-80, XP-80A and YP-80, the need for all of these features was recognized, and they were all eventually added to the aircraft.[16]

The simplicity of the design of the XP-80 was such that an Air Force inspection of a mock-up of the aircraft with a wooden engine could be held near the end of July 1943, little over a month after the production contract was awarded. The Air Force representatives were greatly impressed, and felt that few changes would be necessary. "The construction of the airplane was of such a simplified nature that few changes were suggested; all committee members were pleased

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with its features."[17]

Construction of the fully functional XP-80 continued at a rapid pace. By the middle of August 1943, construction had advanced to the point where the actual engine was urgently needed to finish the work on schedule. Since the engine was to be provided by the British, a number of frantic letters, calls, and transatlantic cables were exchanged to expedite the delivery of the engine. "Lockheed stated that, in view of the rapid progress made on the airplane, an actual engine was urgently needed and requested that immediate action be taken to furnish the power plant for the XP-80."[18] The de Haviland Goblin engine was scheduled to arrive on 1 September 1943, but did not arrive at Lockheed's Burbank plant until 2 November 1943, causing a significant delay in the completion of the prototype.[19] "Information had been received in Washington that the Halford H-1 unit was expected to be ready for shipment approximately 18 Oct. 1943.... Airplane completion was being held up awaiting delivery of the engine."[20] "The H-1 engine arrived at Lockheed on 2 Nov., 1943; as of 9 Nov. It was being installed in the XP-80."[21]

The delays with the Goblin engine, plus a desire to incorporate many of the components excluded from the original XP-80, on 16 September 1943 led Lockheed to propose that they be allowed to construct two additional XP-80 aircraft. These aircraft were assigned the corporate designation L-181 and were to include features to allow for cockpit pressurization and additional fuel tank capacity to increase the range of the aircraft.[22] Also, at least one of these new prototypes would be powered by an improved American version of the British engine, dubbed the I-40.[23] Although the thrust of this American design was increased (4,000 lbs thrust for the I-40 vs 3,000 lbs thrust for the Goblin), it was a far from perfect product. The most significant

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difficulty encountered by the American jet fighter program during the war, much like both the British and German programs, was problems with the jet engine development.

As mentioned previously, the contract for the production of the J36 engine was originally given to the Allis-Chalmers company of Milwaukee, Wisconsin. There were numerous problems and delays, several of which were beyond the company's control, with Allis-Chalmer's manufacturing of the engines. As a result, they produced few engines, far too late to be useful, and those engines that eventually did make their way to the Air Force had substantial manufacturing flaws which precluded their use.[24]

When it became obvious that Allis-Chalmers would be unable to complete the engine contract satisfactorily, it was decided that production P-80s would be powered by the I-40 instead, making Lockheed's L-181 proposal more important than ever. By 1 October, 1943, the Air Force told Lockheed to proceed with construction of the second and third XP-80 prototypes; a formal contract would follow as the project proceeded.[25] Initially, one of these additional prototypes was to use the Goblin engine, and the other the I-40, but eventually both were given the I-40 power plant. These second and third prototypes were eventually designated XP-80A's, to differentiate them from the original XP-80.[26]

Although the I-40 engine was available more reliably than the Goblin or the J36, it still had numerous problems. Originally, the General Electric facility at Schenectady had received the contract to produce these engines, but it eventually became obvious that they were incapable of meeting the production schedule.[27] In May 1945 a supplementary contract was awarded to General Motors Allison Division, located in Indianapolis, Indiana. This engine would eventually be redesignated the J33.[28] Although Allison did a better job of meeting the production schedule,

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there remained problems with their products. In December 1944, before the Allison engines became available, Lockheed complained in a letter to Colonel R. S. Garman of the Engineering Division at Wright Field, listing a number of problems with the engines.

> Lockheed was concerned about the engine situation for the YP-80A and P-80A airplanes and its effect on urgent developmental problems on the P-80A type. The engine situation was critical because Lockheed had received insufficient engines and spare parts. The engine shortage was aggravated by the fact that poor engine design features and poor engine maintenance at Muroc and San Bernardino Air Base kept the engines in an unflyable condition much of the time. Experimental flight testing at Muroc was greatly restricted by power plant failures and by lack of spare parts for engines.[29]

With the arrival and installation of the de Haviland Goblin, the XP-80 (44-83020), nicknamed *Lulu-Belle*, could prepare for flight testing. The parenthetical number above is the serial number, which was unique to each Air Force aircraft. This number has two components, separated by a hyphen. The first is two digits that identify the year the plane was ordered by the government. The next series of digits indicates the sequence of production. The government assigns sequence numbers in batches when contracts are awarded, so planes from the same company's production series will have sequential serial numbers.

The serial number is painted on both sides of the tail of the finished aircraft, as well as under the cockpit on the port side of the plane. When applied to the tail, the dash between the first two digits and the rest is omitted, and it is also standard to drop the first digit from the year indicator, while the cockpit number is painted in its entirety. Thus, the XP-80 serial number, 44-83020, when painted on the tail of the aircraft, would be 483020. Most World War II serial numbers have five digits following the dash, but after the war as production orders shrank, that

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would become four or even three, so most post-war serial numbers are shorter.

The smaller numbers had a chance of repeating, since the decade digit was dropped. If a plane remained in service for ten years, when the number could be repeated, a '0' was added before the first digit. Should the plane remain in service for two decades, a second '0' would be added. Thus 48-129 would be painted as 8129. Ten years later it would be 0-8129, and twenty 00-8129.[30]

Lulu-Belle was completely assembled, weighed, painted (a very attractive scheme of dark green on all upper surfaces and light gray on the undersides) and polished by 9 November 1943. The green color used on *Lulu-Belle* was not a standard United States Army Air Force color. The first P-59's had been painted in the standard scheme of olive drab on the upper surfaces and light gray on the lower ones. The green used on *Lulu-Belle* was deeper and richer, resulting in a very unique and attractive finish. The likely source of the non-standard green paint was Lockheed's contract to build its Hudson patrol bomber for the British Royal Air Force. Those planes were factory painted in standard British colors. *Lulu-Belle* was most likely painted with surplus British green paint.

Although *Lulu-Belle* was finished in what were nominally camouflage colors, her function as an experimental test aircraft meant that performance was more important than low visibility. The smoother an aircraft's surface, the less resistance to the air, and the better the performance. Waxing and polishing *Lulu-Belle* was not something that would normally be done with a combat aircraft, but made excellent sense in this instance.

Lulu-Belle weighed in at 8,606 pounds, only six pounds over the projected weight in the initial specifications. "However, the gross weight of the airplane with normal load was 8,606

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pounds, or six pounds more than the contract weight. Engine information which had not been received until the preceding week had made certain changes in the airplane necessary. These changes had increased the weight of the airplane by approximately 35 pounds."[31]

She was completed and ready for testing in 145 days, improving on her contracted delivery schedule by more than a month. "The XP-80 had been completed 145 days after receipt of the letter of intent, and Engineering Division (Wright Field) felt that Lockheed should be commended for the example of accelerated production of an experimental airplane. Personnel of the Engineering Division who had seen the airplane had remarked on its exceptionally fine workmanship."[32] This accomplishment is even more remarkable considering that the XP-80 was a fully functional combat aircraft, with armament, armor and self-sealing fuel tanks. On 13 November, 1943, she was partially disassembled and trucked to Muroc for flight testing.

Once at Muroc, various ground tests were conducted on *Lulu-Belle* before attempting the first flight. On 17 November 1943, during one of the final tests before flight, when the engine was run up to full power, both air intake ducts collapsed inward nearly simultaneously from the suction exerted by the airflow. Kelly Johnson, who was standing nearby, was nearly drawn into the collapsing ducts himself.[33] The collapsing ducts shed various small bits of metal, which were ingested by the engine before it could be shut down. This accident resulted not only in the need to rebuild and strengthen the air intake ducts, but to remove and completely disassemble the engine to check for damage from the ingested material.[34]

With the engine removed and returned to the Burbank plant, it was disassembled by Guy Bristow, an engineer on loan from de Haviland, the firm that manufactured the engine. Not only did Bristow know the engine intimately, he was also the only person at the plant with the proper

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tools to match the metric nuts and bolts of the engine's English construction. Remarkably, the disassembled engine showed virtually no damage. Until near the end of the process, that is. It was then that Bristow discovered a crack in an impeller vane. [35] The impeller is a large, flat disk with small airfoils, or vanes, on it. It is part of the air compressor assembly. By spinning rapidly, it draws air into the engine and compresses it so that the engine will function. It is a single unit, and not designed to be disassembled or repaired. Interestingly, this crack apparently had nothing to do with the collapse of the air ducts, but rather resulted from a flaw in the forging of the part. This crack had the potential for causing a disastrous and quite possibly lethal engine failure in-flight, and was not repairable. This meant that another engine must be procured from England, delaying *Lulu-Belle's* first flight by approximately a month. However, since this discovery significantly increased the chances that the test pilot would survive the first flight of the aircraft, the accident proved a blessing in disguise.

While waiting for the arrival of another Goblin engine, Lockheed revived an idea they had considered before. They proposed to the Air Force that an I-16 engine be installed in the XP-80 and the aircraft tested with this power plant. The I-16 was available in some quantity as a result of the XP-59 program. This idea was put forth not only because of the immediate problem with the original engine of the XP-80, but also "because of the general situation in regard to H-1 units; it appeared unlikely that more than two H-1 units would be available for the project before July or August 1944."[36] Although the Air Force gave tentative approval to this project, it ultimately came to nothing, as "it was felt that very little useful information could be secured from the use of the I-16 engine."[37] The primary reason for the reversal of the decision in this case was the difference in power output between the two engines - the H-1B Goblin developed 3,000 lbs of

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thrust, while the I-16 only 1,600 lbs of thrust, just over half of the Goblin.

Finally, on 29 December 1943, the second Goblin power plant arrived at Burbank. Lockheed installed the new engine and promised flight testing about 3 January 1944.[38] The damaged air intake ducts had previously been repaired and strengthened, adding about 30 pounds to the aircraft's weight.[39] *Lulu-Belle* was again transported to Muroc, and following various tests was finally pronounced ready for her maiden flight. Following some weather-induced delays (recent heavy rains had rendered the surface of the dry lakebed too soft for flight operations, and flight testing had to wait until the lakebed dried sufficiently), *Lulu-Belle's* first flight was scheduled for 8 January 1944.[40]

A small crowd of engineers, mechanics and government representatives gathered on that cold, gray morning. Kelly Johnson had some final instructions for Lockheed's chief test pilot, Milo Burcham. "Just fly her Milo. Treat her nice -- and find out if she's a lady or a witch."[41] At 9:10 am, Burcham gradually eased in the throttle, speeding *Lulu-Belle* across the lake bed. As she reached 110 mph, Burcham gently lifted her off the surface of the lakebed. Five minutes later, to the disappointment of all present, *Lulu-Belle* was back on the ground. Burcham had been unable to get the landing gear to retract, and had been uneasy about the lateral sensitivity of the controls - the airplane seemed very "touchy" about rocking back and forth. The landing gear problem was simple enough - a safety lock had recently been installed to prevent the accidental raising of the landing gear, and Burcham was unaware of this feature. Telling him about it eliminated one problem. Kelly Johnson addressed the second problem by reminding Burcham about the hydraulic boost to the ailerons, and suggesting that maybe he was over-controlling. With the problems apparently solved, Burcham prepared for a second takeoff.[42]

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At 10:00 am Burcham gently lifted *Lulu-Belle* from the lakebed once again. The landing gear retracted with no problems on this second attempt. *Lulu-Belle* climbed away to perform some preliminary tests, and the anxiety of the small crowd on the ground was palpable. Would *Lulu-Belle* fulfill the promise of her sleek looks, clean lines and powerful engine? Or would she be a sub-par performer, like the P-59, or even worse, would she have unforseen control problems? Was *Lulu-Belle* a witch?

Suddenly, diving out of the gray desert sky toward the crowd, came *Lulu-Belle*. Reaching speeds up to 490 mph during the dive, Burcham pulled out scant feet above the desert floor. He leveled out and pushed the throttle to the wall, and made a screaming high-speed pass over the crowd. Flashing over the stunned observers at 475 mph, Burcham pulled up into a steep climb, doing a series of dazzling aileron rolls as he climbed. As the crowd erupted into joyous bedlam, there was no longer any doubt in the minds of those watching - *Lulu-Belle* was every inch a lady.[43]

Even as *Lulu-Belle* was being prepared for her first flight, Lockheed continued the process to produce an improved version of the prototype, the XP-80A. The final agreement with the Air Force called for two XP-80A's, with increased range, cockpit pressurization and poor visibility capability. The cost for these two machines would be $444,782 plus a four percent fee of $17,791.[44] Although originally Lockheed had planned to build one of these machines with the de Haviland Goblin engine and the other with the more powerful American I-40, difficulties in acquiring the Goblin led them to construct both machines with the I-40 engine. Again, Lockheed promised rapid delivery of the machines, with the first to be delivered to Muroc within 150 days of approval, and the second within 180 days.[45] Time was beginning to be an issue, as reports of

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the successes of the German jet program had the Air Force in a state of nervous anticipation, fearing what a swarm of uncatchable jets could do to their bomber fleets.

Shortly after Lockheed submitted the proposal for the XP-80A aircraft, the company submitted another proposal. This one was for the construction of thirteen additional pre-production L-140 aircraft, plus one static test model. These aircraft were to be powered by the de Haviland Goblin engine. The cost for these machines was to be $226,200 plus a four percent fee of $9,048 per machine. Lockheed proposed to have the first of these machines available in August 1944, one more per month in September and October and two per month following that, until March 1945. This delivery schedule was based on Lockheed receiving a letter of contract by 12 February 1944.[46]

The Air Force was very interested in this proposal, and wished to expedite the approval process, to allow Lockheed to begin construction. They asked Lockheed to make only one change. Problems with the manufacture of the J36 engine were already obvious, and the Air Force insisted that these additional thirteen machines use the I-40 engine instead. So modified, the Air Force designated these machines YP-80A's and gave Lockheed the go ahead on 22 February 1944.[47]

By this point, the Air Force was very interested in the P-80 program, and on the basis of the early tests of *Lulu-Belle* concluded that the P-80 was what they were looking for in a jet fighter; that "the P-80A was definitely considered to be a tactical airplane."[48] The Air Force, based on Lockheed's projections, believed that the P-80 could begin entering operational service in the summer of 1945, and asked Lockheed to undertake measures appropriate for the production of 500 P-80A's. This recommendation was first made on 16 February 1944, and was

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formalized by a statement of intent on 9 March 1944 and a formal letter of contract on 4 April, 1944.[49] This contract for 500 P-80A-1 aircraft, spare parts, tools, ground handling equipment, and engineering data stipulated payment of $64,555,000 plus a four percent fee.[50] Within two months of this date, the Air Force was holding conferences with Lockheed to discuss the possibility of increasing the production of P-80's to *450 per month* by 1946.[51] All of this based on the test flights of one aircraft!

Lulu-Belle continued to make test flights, to discover her capabilities and the problems that are always inherent in a new aircraft design. Along the way, *Lulu-Belle* set a number of performance records. Among the most significant of these was that during flights conducted between 15 February 1944 and 9 March 1944, *Lulu-Belle* became the first American aircraft to exceed 500 mph in level flight. "It was the first AAF airplane to exceed 500 mph in level flight; high speed at 20,480 feet at 9,500 rmp was 502 mph T.A.S."[52] In fact, the Air Force considered *Lulu-Belle* to be not only "the fastest American airplane"[53] but also "possibly the world's fastest at all altitudes up to 32,000 feet."[54] The optimism and pride of the American Air Force officers was understandable but misplaced. The Me 262 had already reached speeds of 540 mph, and the rocket-powered Me 163 was capable of over 600 mph. However, the Air Force had not yet encountered either type in combat, and so was unaware of the extremely high performance of the German jets.

Normally, during test flights, the test pilot not only had to fly the aircraft, performing the specific maneuvers called for by the tests, being alert for any potential problems with the aircraft, but he also had to make notations about the technical aspects of the aircraft's performance. To aid in this requirement, *Lulu-Belle* had a second instrument panel installed in the nose armament

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bay. A 35mm camera was secured in place to photograph the panel at regular intervals, determined by a timer. This technique would give the engineers important information they needed to evaluate *Lulu-Belle's* flights.[55]

As *Lulu-Belle* was put through her paces, the overall evaluation of her flying characteristics was excellent. This did not mean that she was without problems. The most noticeable of these problems involved her stall characteristics. An aircraft *stalls* when there is insufficient airflow over the wings to create enough lift to maintain flight. Ideally, when a plane stalls, the nose simply drops towards the ground, allowing flight to resume, but other reactions, including rolling, are possible. The most severe and dangerous of these reactions is the *spin*. This is an uncontrolled tumbling of the aircraft. One of the reasons an aircraft stalls is when it climbs or turns at too steep an angle for an extended period. This not only reduces the plane's speed but also disrupts the airflow over the wings by putting them in an increasingly vertical orientation, rather than the standard horizontal flight position. The other, and far more common, reason for an airplane to stall is simply when it is moving too slowly. This, unfortunately, will happen every time a plane attempts to land. A landing is, in fact, a controlled stall. An aircraft's stall characteristics are extremely important in determining how easy it is to land.

Pilots prefer to fly a plane that gives ample warning of an impending stall, often by becoming mushy or unresponsive on the controls. *Lulu-Belle*, however, gave no notice that a stall was about to occur. Further, if a stall was entered with the flaps down (as would be the case when landing), *Lulu-Belle* displayed an alarming tendency to try to roll sharply to the right. There were a few other minor directional stability problems, especially at high speed. The other potential problem was a tendency for the exhaust tailpipe temperatures to run hotter than

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predicted or allowed by the design.[56]

The problems with the stall characteristics were solved by adding a fillet to the leading edge of the wings. A fillet is a thin piece of aluminum or similar material, used to change the shape of a particular portion of the aircraft. Fillets are commonly added to wings, wing roots, or the tail assembly, almost always to overcome some sort of stability problem. Fillets are usually used to smoothly blend the wings into the fuselage, and are sometimes used to make small "fins" on the rear of the fuselage, near the tail assembly. Prior to computer modeling, the only way to determine an aircraft's performance and handling was to actually build it and fly it. An otherwise excellent plane might need a minor shape modification to fix a problem, and this was the primary role of fillets.

The other directional stability problems were overcome by combining two fixes - changing the original squared-off wing and rudder tips to rounded ones, and by slightly raising (1 ½ degrees) the leading edge of elevators.[57] With these corrections, the performance of the XP-80 was considered to be outstanding. Overall maneuverability, rate of roll, zoom climb, and the ability to maneuver at high G loads, were considered especially good. This information was particularly encouraging as *Lulu-Belle* conducted many of them with her engine downrated from 3,000 lbs thrust to 2,240 lbs of thrust, in order to prolong the life of the engine.[58]

These tests were exciting, as they helped the United States break the barriers of high-speed flight, and they certainly whetted the Air Force's desire for the production P-80 aircraft. However, as the later models of the P-80 were all going to be equipped with the I-40 engine, these tests could not be considered completely indicative of the potential of the P-80. *Lulu-Belle* participated along with many other aircraft, including a P-59, in a series of tests in the summer of

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1944 to analyze the impact of jet fighters attempting to intercept and escort the large four-engined strategic bombers. These tests concluded, unsurprisingly, that the best counter for an enemy jet fighter was another jet fighter.

> It was concluded that the best method of effecting defense against high speed jet fighter aircraft was with high speed jet fighter aircraft. Assuming enemy jet aircraft to have performance comparable to U.S. jet aircraft, there was no defense for a conventional fighter against a jet fighter in individual combat except by the use of natural aids such as clouds, sun and camouflage.[59]

Following these tests, and with both of the XP-80A aircraft finished and the YP-80A aircraft about to come off the assembly line, *Lulu-Belle's* record-setting days were over. It was proposed to send her to Europe to escort photo reconnaissance planes that had encountered German jets, but a YP-80A was to be sent instead.

> It appeared that he has been requested by Washington to study the possibility of sending two P-80's to U.K. very soon. Information had been secured from Fighter Br., Prod. Eng. Sect., that the airplanes were to be used for escorting photographic airplanes which had encountered trouble with German jet airplanes. Use of the XP-80 and the second YP-80A had been recommended. [60]

Lulu-Belle was then assigned to the 412th Fighter Group for evaluation and transition training. This did not go especially well. *Lulu-Belle* experienced serious problems with fuel leakage in her aft fuselage, and was still having problems with tailpipe temperature.[61] Eventually *Lulu-Belle* was transferred back to Muroc for additional tests on improved models of the de Haviland Goblin engine. There she became something of a "hanger queen," spending far more time on the ground undergoing repairs than in the air.[62]

Her useful life at an end, *Lulu-Belle* was transferred to the Museum Storage Depot at Park Ridge, Illinois, on 8 November 1946 as part of a collection of historic aircraft assembled by

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General Arnold. On 1 May 1949, the Smithsonian Institution officially took possession of *Lulu-Belle*, and had her crated and shipped to its aircraft storage and restoration facility in Silver Hill, Maryland. There she remained until 1976, when the decision was made to restore the aircraft to its original condition. This restoration work, well detailed in E.T. Wooldridge, Jr.'s book ***The P-80 Shooting Star: Evolution of a Jet Fighter*** by Smithsonian Institute Press, was completed in 1978. *Lulu-Belle* is currently on display in the National Air and Space Museum of the Smithsonian Institution.[63]

The first of the XP-80A (44-83021) prototype aircraft was completed on 3 June 1944. This aircraft was finished in 132 days, again improving on the 150 day promised delivery schedule.[64] The aircraft was taken to Muroc for evaluation and test flights. This aircraft was named the *Gray Ghost*, because of it's paint scheme. Unlike *Lulu-Belle* which had been dark green above and light gray underneath, the *Gray Ghost* was painted entirely in a light gray color. Like *Lulu-Belle*, *Gray Ghost* was highly polished.

On 10 June 1944, *Gray Ghost* prepared to make her first flight. One of Lockheed's senior test pilots, Anthony (Tony) LeVier, would take the controls for her maiden flight. Someone seeing *Lulu-Belle* and *Gray Ghost* together might have had some difficulty noticing any differences between the two planes beyond their color, but the differences were there. In addition to the newer and more powerful I-40 engine, enlarged fuel tanks, and cockpit pressurization system, all of which were internal and therefore not immediately obvious, there were some external differences between the two planes. Primarily to accommodate the larger and heavier engine, *Gray Ghost* was slightly larger - a fuselage of 34 feet 6 inches, increased from 32 feet 10 inches in *Lulu-Belle*, and a wingspan of 38 feet 10 ½ inches, increased from 37 feet. The tail fin,

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using the rounded tip *Lulu-Belle* introduced, was also taller than *Lulu-Belle's*. Another difference was the location of the air intake ducts for the engine. Lulu-Belle's intake ducts were forward of the cockpit, while *Gray Ghost's* were moved back to a location roughly parallel with the aircraft's windscreen. Gray *Ghost* was considerably heftier than *Lulu-Belle*, weighing in at 13,780 pounds to *Lulu-Belle's* final modified weight of 8,916 pounds. As a result of this increased weight, *Gray Ghost* also had considerably sturdier landing gear than *Lulu-Belle*. All of these changes would be standard on all subsequent models of the P-80.[65]

Gray Ghost's first flight, much like *Lulu-Belle's*, was not particularly successful. The flight lasted only 35 minutes and was marred by the failure of the flaps. Aircraft have two types of control surfaces on the wings - *ailerons* and *flaps*. Ailerons are located near the tips of the wings, and are used to control the plane in flight. When the pilot moves the control stick to one side or the other, the ailerons move to allow the plane to *bank*. If the stick is moved to the left, the left aileron moves up while the right one moves down. This decreases the lift on the left wing and increases it on the right, which causes the airplane to tilt to the left. Flaps are located close to the fuselage, and are either retracted (level) or lowered. When lowered, flaps alter the shape of the wing and increase lift. They are used primarily for take-offs and landings.

During *Gray Ghost's* first flight, the right flap extended but the left one refused to do so. The right flap then could not be retracted, nor the left one extended. This created an asymmetrical lift situation, where the right wing, with the flap extended, produced more lift than the left wing, giving the aircraft a strong tendency to try to roll to the left. LeVier, showing the skills demanded of a test pilot, managed to bring the contrary machine in for a safe and undamaged landing on the dry lakebed. The flap mechanism was soon fixed, and test flights

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resumed.[66]

Another disturbing problem on the first flight was a distinct tendency for the *Gray Ghost* to "porpoise," that is, for the nose to point first up, then down, like a porpoise swimming along the surface of the ocean. This was attributed to the designated center of gravity being located too far to the rear of the airplane, causing it to be slightly tail-heavy. This was solved by adding lead ballast to the nose of the *Gray Ghost*.[67]

The next few flights revealed several more problems, none of which had been encountered before. All of them were potentially serious, and needed to be addressed to keep the P-80 program on track.

The most immediate of these problems was cockpit temperature. During the third test flight, which was a speed trial, enormous amounts of extremely hot air (325 degrees Fahrenheit) from the engine came pouring into the cockpit during flight.[68] This was not merely annoying or uncomfortable, but extremely dangerous to the pilot. The cockpit became so hot (average temperature of 185 degrees Fahrenheit) that LeVier was unable to touch any of the cockpit controls, and developed heat blisters on his arms. [69] The immediate cause of the problem was a faulty cockpit pressurization valve, but the extended fix involved redesigning the cockpit pressurization system to incorporate a cooling system, to prevent any similar occurrences.[70]

Another problem common not only to all early P-80's but indeed to all early jet fighters, resulted from very primitive fuel controls. The engine's extreme sensitivity to variations in fuel flow meant that pilots had to exercise extreme caution when manipulating the throttle or risk a flame-out, or worse. Tony LeVier had this to say about the problem:

> Those early fuel controls were so underdeveloped; nothing but the

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> utmost caution in handling of the throttle would prevent melting the engine hot section into a spewing white-hot molten mass of hardware. Throttle bursts were strictly forbidden. A ground start was so difficult only selected personnel were allowed to run up an engine. When the engine would "light-up", you had to nurse the throttle between idle and cut-off to prevent flames shooting 20 feet out from the tail-pipe. The Turbine Inlet Temperature would go off the scale in the "blink of an eye."[71]

Although the thottle control problems were soon corrected by the addition of a fuel regulator to the throttle, the other problems were not so easily solved. As both were peculiar to high-speed jet flight, neither had been encountered before in piston-engined aircraft. These problems were, therefore, both given names by the people who first encountered them. One of these mysterious new problems was a phenomenon that was called "duct rumble." At certain combinations of speed and throttle setting, strange and unnerving noises came from the air intake ducts. The P-80, at least from the pilot's perspective, was an extremely quiet airplane to operate, especially for pilots used to the awesome roar of the large piston engines. Pilots often described the P-80 as "whispering" or "swishing" in flight. So this unexpected and loud noise from the duct system was cause for great concern. The noise was variously described at different times as a deep rumbling or even a bass note, such as a large pipe organ would produce.[72]

Complicating efforts to identify and solve the problem was the fact that duct rumble only occurred intermittently. It also seemed to have little or no effect on the physical structure of the aircraft itself, aside from a tendency for the nose of the aircraft to "snake" from side to side in flight when the rumble was occurring.[73] Aside from being rather hard on the nerves of the pilots, duct rumble did not seem to actually threaten the safety or viability of the P-80. This problem would take some time, and the efforts of Kelly Johnson himself to correct.

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Before examining the second of the P-80's problems, a brief discussion of some of the mechanics of high speed flight may be useful. In particular, a definition of the Mach number and the critical mach number will be provided. The *Mach Number* is named after Ernst Mach, an Austrian physicist, and relates to the speed of sound. Mach 1 is exactly the speed of sound, Mach .75 is three-quarters the speed of sound, and Mach 1.5 is one and one-half times the speed of sound. The reason Mach numbers are used instead of actual speed measurements is that sound is a pressure, or displacement, wave, and it's speed varies depending on the density of the medium through which it is moving. The denser the medium, the faster sound moves. This means that Mach 1 is well over 700 mph at sea level where the air is quite dense, but is only around 600 mph at higher altitudes where the air is thinner.

As an aircraft flies through the air, it displaces the air, creating turbulence. At speeds well below or above Mach 1, that turbulence does not severely affect the aircraft. But right near Mach 1, that turbulence is a problem, because both the turbulence and the aircraft are traveling at approximately the same speed. This causes the turbulence to remain on the surfaces of the aircraft, and can lead to a number of nasty problems, such as compressibility, where the control surfaces become frozen or damaged by this turbulence.

The *critical mach number* of an airplane is the exact speed *for that particular airplane* at which this problem emerges. The critical mach number varies from plane to plane due to differences is the shape of the plane. The higher the critical mach number, the faster the plane can fly before experiencing turbulence-related problems. The swept wings of the Me 262 gave it a higher critical mach number than either the British Meteor or the American P-80. This was the main reason the Me 262 was faster than both of those planes, despite all three of them having

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approximately the same thrust available from their engines. Swept wings would in fact provide the means to "break the sound barrier" by delaying compressibility right up to Mach 1.

Because of these characteristics of high-speed flight, the problem with the XP-80A that involved the control surfaces - specifically the ailerons - was potentially the most dangerous. At high speeds, especially those approaching the critical mach number, the ailerons would begin to oscillate without any pilot input. This ranged from a relatively minor twitching of the rear of the aileron to a rapid and violent fluttering of the entire aileron. This movement of the ailerons became known as "aileron buzz."[74] This motion could be very hazardous, as it had the potential to either destabilize the aircraft in flight, or damage the ailerons. Since the ailerons, along with the rudder, elevators, and flaps, are part of the "control surfaces" that enable the pilot to steer, or control the airplane, damage to them could have dangerous or even fatal consequences. Both duct rumble and aileron buzz would require considerable time and effort to solve. Both Lockheed and NACA were involved in finding solutions to these problems. The solutions to these problems would not only allow the P-80 to continue to develop, but would also prove useful for future designers of jet aircraft.[75]

The second of the XP-80A (44-83022) prototypes was completed on 27 July 1944. This was only three days ahead of the official Air Force delivery date, and two weeks later than Lockheed's own corporate delivery schedule. The reason for this delay was that Lockheed decided to modify the configuration of this aircraft. The decision to modify the plane was made when Lockheed was informed that the engine for the plane would not be shipped until 24 June, 1944. This information proved to be incorrect, and the original, earlier engine ship date was in fact accurate. By the time Lockheed was aware of this, it was easier to complete the modification

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than to return the plane to the standard configuration.[76] The modification entailed adding a second seat to the cockpit, immediately behind the pilot. This seat was for an observer or flight engineer, and was provided with a great deal of extra instrumentation to allow for additional tests and measurements.[77] This aircraft, delivered unpainted to assess any difference in performance with and without paint,was naturally named *Silver Ghost*. The first flight of *Silver Ghost* took place on 1 August 1944, and was uneventful.[78]

Both Lockheed and the Air Force were interested in assessing the difference (if any) between painted and unpainted aircraft, especially at high speeds. An aircraft painted with a gloss lacquer, such as was used on *Gray Ghost*, actually has a smoother surface, and thus lower drag than an unpainted one. The trade-off is in weight - the quantity of paint used to cover even a single-seat aircraft can weigh dozens of pounds. Both Lockheed and the Air Force conducted tests on painted vs. unpainted aircraft, and their results were similar. Both types of aircraft had almost identical top speeds, but the painted aircraft had a moderately higher cruising speed (the speed when using the most economical fuel setting - used to travel long distances). All early production P-80's were painted gloss gray, but the practice was discontinued on the 470th aircraft. Painting the planes took time and cost money, made the planes harder to maintain (the paint deteriorated) and as the paint degraded, so did the aircraft's performance.[79]

Silver Ghost proved instrumental in helping to diagnose and cure the duct rumble problem. Kelly Johnson decided that he needed to ride in his own creation to help cure the problem. Johnson, in fact, often rode in his own airplanes to see for himself just how they performed. Johnson described his motivation for doing this in a filmed interview for a Lockheed tribute to him: "I decided at an early age that unless I had the hell scared out of me once a year, I

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wouldn't have the proper balance to really design new airplanes of any type."[80] While in the air aboard *Silver Ghost*, Johnson experienced duct rumble for himself, and was able to correctly diagnose the problem.

Duct rumble, although mysterious, was in reality a fairly simple phenomenon. At certain speed and power settings, the airflow into the engine became uneven, with the air immediately adjacent to the aircraft's skin moving more slowly than the rest of the airflow. Just as water flowing around turns or obstacles produces turbulence and sound - the "babbling brook"- so too, uneven high-speed airflow creates eddies, turbulence and noise. In much the same way as blowing across the top of an empty bottle can produce an harmonic tone, so the uneven airflow in the intake duct produced the characteristic rumble or organ note. The uneven airflow also accounted for the tendency of the plane to "snake" when this occurred. Johnson's solution to this problem was simple, elegant and successful. He devised what was referred to as a "boundary layer bleed," a shallow series of ducts that lay inside the main air duct, against the fuselage. These new ducts channeled the slower-moving air near the skin of the airplane to exits on top and bottom of the air duct, preventing this slower-moving air from interacting with the main airflow.[81] This solution eliminated duct rumble on the P-80 aircraft. Because of the time it took to analyze the problem and devise a fix for it, the earliest production P-80's did not have this feature, but all of the later machines did.[82] It was later discovered that some of this "wasted air" could be rerouted to power ancillary systems and even to provide additional lift for the aircraft's control surfaces. The boundary layer bleed system eliminated a problem that, while not actually hazardous to the airplane, was extremely nerve-wracking for the pilots.[83]

Aileron buzz proved to be a more resistant problem. It was quickly discovered that the

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cause of the problem was the turbulence in the airflow over the wings caused by flight near the critical mach number. This uneven airflow would then buffet the ailerons, with serious potential for damage to the aircraft. Both Lockheed and NACA conducted engineering studies, test flights and wind-tunnel tests to find a solution to the problem. A number of ideas were tried, including alternately increasing and decreasing both the static and dynamic balance of the ailerons, increasing the wing torsional stiffness, putting counterweights on the wingtips, installing flutter dampeners and changing the contours of both the wing and the ailerons.[84] None of these proved successful. The final, successful solution to the problem consisted simply of increasing the tension on the internal control cables of the ailerons to 350 pounds of pressure, which gave them enough stiffness to resist the turbulent air.[85]

While all of these flights, tests and modifications were undertaken, the first of the YP-80A's were completed. The first of the YP-80As (44-83023) was flown on 13 September 1944. This aircraft was then assigned to NACA for high speed and wind tunnel testing. The second YP-80A (44-83024) was delayed due to a decision to convert it to a photographic reconnaissance aircraft. The nose armament was removed, and photographic equipment was installed in the bay. This aircraft was redesignated the XF-14. Consequently, the third YP-80A, (44-83025) was actually the second completed, being delivered on 10 October 1944.[86] This aircraft was to be central in the first major tragedy of the P-80 program.

On 20 October 1944, the third YP-80A took off on its first flight, from Lockheed's airfield in Burbank,with Milo Burcham at the controls - his first time in a YP-80A. Test flights were now being conducted from Burbank as well as Muroc, in an attempt to speed up the testing process.

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> As a result of the AAF's request to Lockheed to expedite production and delivery of P-80 airplanes, Lockheed had requested permission to fly the airplanes at Burbank instead of Muroc. It had been decided that the airplanes would be flown and flight tested at Burbank, and action was to be taken to convey this information to Western District and to Lockheed.[87]

Less than a minute into the flight, at only about 300 feet of altitude, it became obvious that something was wrong. The landing gear and flaps had been slow to react, which may have meant that the engine had failed. The plane made a sharp turn to the right, and began to glide back to earth, but ended up crashing into the side of a gravel pit. Burcham was killed instantly, and the plane was destroyed and partially burned. Burcham's loss was a severe blow to his friends and colleagues, but the pressures of wartime development meant that the program must continue. Tony LeVier was promoted to chief test pilot, and work continued.[88]

The cause of the crash was determined to be a sheared drive shaft connected to the main fuel pump. This caused the pump to cease operating , resulting in a loss of fuel flow to the engine, and a flame out.[89] As a result of this tragedy, backup electric fuel pumps were installed on all subsequent P-80's.[90] This would not, however, be the last time fuel pump failures contributed to tragedy in the P-80 program.

The fourth through seventh YP-80As (44-83026 to 44-83029) had quite a different fate in store for them. By the fall of 1944 German jets such as the Me 163 and especially the Me 262 were making their presence known in the air combat over Europe, although in small numbers. Pressure was increasing from American commanders in Europe to provide a counter for these German aircraft. It was decided that something must be done to demonstrate to Allied airmen that their side too had jet fighter planes. Thus, on 14 November 1944, was born Project

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Extraversion.[91]

Extraversion was a straightforward project. The four YP-80A's were crated up, along with sufficient spares, ground support equipment and service personnel, and were shipped to Europe. There they would be flown to various Allied airbases and put through their paces. There were two reasons for this. The primary purpose was to help Allied pilots develop tactics for use against jet fighters. But it would also prove to Allied fliers that Germany was not the only country with jet fighters. Despite being armed and equipped as fighters, these planes were *not* to participate in combat, but only give flight demonstrations at Allied airbases. Two of the YP-80A's (44-83026 and 7) were sent to England (European Theater of Operations, or ETO) and the other two (44-83028 and 9) were sent to Italy (Mediterranean Theater of Operations, or MTO).[92] The aircraft were shipped from the Lockheed plant by 19 December 1944.[93]

The two aircraft assigned to the MTO arrived in January 1945, and performed their duties without incident through the end of the conflict in Europe. The planes assigned to the ETO were not so fortunate. They arrived and were assembled, and made their initial flights on 27 January 1945. On 28 January 1945, one of these two aircraft, (44-83026) was making a local test flight when it exploded violently, instantly killing its pilot, Major P.A. Borsodi.[94] While the causes of this accident were being investigated, the other plane in England was temporarily grounded. It was recommended that all P-80's be grounded pending the results of the accident investigation.[95] However, only the other YP-80A in England was in fact grounded.

The cause of the accident was apparently a failure of the tailpipe flange, which connected to the tailcone in the engine, and helped regulate and control the exhaust gases. The failure in flight had created a fire, which in turn set off the explosion.[96] Despite what was obviously a

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serious structural failure, all other P-80's except for the other YP-80A in England continued to fly. The official justification for this decision read, in part

> In view of the fact that the YP-80 airplane which crashed in the U.K. had only 35 minutes of flying time and in view of the extreme importance of the production program, it was not considered advisable to ground any of these airplanes within the continental limits of the U. S.[97]

The YP-80A in England was eventually restored to flight status and continued to carry out its Extraversion role until the program ended with the end of the fighting in Europe. This aircraft was then left in England, and given to the British to facilitate testing of new Rolls Royce engines. It functioned in this capacity until damaged by an engine failure during climbing tests.[98]

The other YP-80A aircraft were used as follows: the eighth was sent to the NACA lab in Cleveland, the ninth to ATSC (Air Technical Service Command) at Muroc for accelerated service tests, the tenth, eleventh and twelfth went to ATSC at Muroc for accelerated service tests and then to the 412th Fighter Group, and the thirteenth to Proving Ground Command.[99] All of these aircraft were delayed by Project Extraversion. In order to get sufficient parts to finish the Extraversion aircraft, and the necessary spares to allow those aircraft to continue to function, the other YP-80A aircraft were cannibalized. This left them short of the parts they needed to function, and some of the engines were not received by Lockheed on time either. Had Extraversion not intervened, all thirteen YP-80A's would have been completed on or ahead of schedule. As it was, all were finished and accepted by 14 February 1945.[100]

During the production and testing of the various prototype P-80's, the Air Force's enthusiasm for the plane continued to increase. Even before the final paperwork was finished on the original contract for 500 P-80A's, it was increased on 5 September 1944, to 1,000 planes, for

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a total cost of $83,093,220. The cost breakdown was as follows: the first 500 airplanes at $76,049 each, the second 500 planes at $55,845 each, spare parts equivalent to 25% of the planes at $16,486,750 and special tools at $659,470.[101] The price per unit for the second group of 500 airplanes was a tribute to the simplicity of the P-80's design, as this price was only $3,000 more than that paid for the construction of America's premier piston-engined fighter, the P-51D Mustang.[102]

The Air Force was not content with the terms of the original P-80 order, however. Discussions were held with Lockheed about the possibility of increasing production of the P-80 by reducing their output of P-38 Lightning fighters. After considerable discussion, it was determined that although a small reduction in the P-38 production could free up resources and manpower to aid in the construction of P-80's, the planning necessary to integrate this into overall operations meant that no acceleration of the P-80 delivery schedule could be anticipated. Essentially, Lockheed could eventually produce more P-80's per month by reducing P-38 production, but could not produce the P-80 any more quickly.[103]

In December 1944, eager for additional P-80's, the government turned to other aviation companies for production facilities. It was fairly common during the war for one company to produce an aircraft designed by another company (Goodyear built the Corsair, designed by Chance-Vought, General Motors built the Wildcat, designed by Grumman). However, this did not necessarily mean that aircraft built by different companies were identical. Most of these companies were, after all, competitors in a difficult business. While most of the basic tooling and jigs for the major components would be provided by the original company for copying by the new contractor, many of the smaller parts had to be fabricated by the new company. On occasion, the

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new company would also improve the original product. As an example, GM took over Wildcat production because Grumman was tooling up to produce the new and improved Hellcat. GM then modified the Wildcat by adding a new and more powerful engine and a taller rudder.

The government received bids from the North American Aviation and Glen L. Martin companies for building 1,000 P-80's.[104] On 19 January 1945 North American was awarded the contract with a bid of $56,775,000 for 1,000 airplanes and spare parts not to exceed 25% of the order.[105] These aircraft were to be identical with the planes made by Lockheed, and would be designated the P-80N. Lockheed immediately began to share the information necessary to enable North American's Kansas City plant to begin producing P-80's. The first P-80N's were expected to be delivered in August 1945.[106]

The main concern over the degree of similarity between two companies' products is interchangibility - can parts made for one company's machine be used on the other's? In the case of the P-80, Lockheed held out for minimal parts compatibility, while the Air Force demanded total compatibility. In the end, Lockheed was forced to give North American more tooling than they had hoped to, and the Air Force, in the interests of speeding up the program, was forced to accept less than complete interchangibility.[107]

These initial contracts were only the beginning of a flood of Air Force orders for the P-80. By 15 February 1945, various government contracts for the P-80 through 1946 produced a total of 9,066 airplanes - 6,631 from Lockheed and 2,435 from North American.[108] Lockheed was not expected to achieve serious monthly production until November or December of 1945, but the expectation was to raise the construction rate to 30 planes per day by early 1946[109] (this was decreased to 10 per day following the surrender of Germany).[110] In fact, on 29 January 1945, the

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Air Force classified the P-80 as one of it's two most urgently needed airplanes, along with Boeing's massive B-29 Superfortress bomber.[111] By this point, Air Force officers were not only willing, but eager to increase the production of the P-80, even at the cost of serious disruption of the production of other important Air Force aircraft. "'I want now to produce the P-80 in quantity soon and am ready to accept substantial losses in other aircraft production if necessary.'"[112] The P-80 had become the Air Force's showcase fighter, a plane that demonstrated that the Air Force was on the cutting edge of this new technology, and they were quite proud of it.

> The P-80 airplane was considered to be the cheapest, the best, and the most quickly developed high performance fighter in this war.... The P-80 would be in quantity production in March, 1945, 21 months from the date the airplane was started, and this was said to be an unprecedented small lapse of time between the beginning of airplane design and the start of production.[113]

Although American officials were justifiably proud of the speed with which the P-80 went from design concept to production combat aircraft, the record for speed in that category goes to a German jet, the Heinkel He 162. In September 1944 the German government issued specifications for a small, lightweight and inexpensive jet fighter, to be built at least partly of non-strategic materials (ie; wood, which was cheaper and more available than aluminium). Heinkel won the competition by the end of September, and by performing the various stages of aircraft development (prototype, testing, modification, production) essentially simultaneously, over 1,000 He 162's were expected to be produced by April 1945, less than 8 months after the project was initiated.

The P-80 went from design concept to flying prototype in 7 months, an impressively quick

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development. The He 162 went from concept to flying prototype in 3 months, an amazingly fast period. Of course, the initial prototype He 162 came apart in the air, and the production machines had a few nasty handling characteristics that would have been eliminated with a longer development period, but no other jet aircraft even came close to this short development time. Within 8 months of the initial concept, He 162's were being received by combat units of the Luftwaffe and over 1,000 were in various stages of production, while the P-80 never did get into combat and only a handful had been produced, after more than 2 years of development. Of course, Nazi Germany was under a certain amount of time pressure by late 1944....[114]

Despite (or perhaps because of) the fact that the P-80 had progressed from paper concept to finished production aircraft in near record time, neither the plane nor the project as a whole were free of bugs.

> Two major problems confronted P-80 production: (1) engine acceptability and availability, and (2) precision tooling. The critical I-40 engine situation was expected to by relieved within two months when Allison engines became available..... Lockheed had been slow getting into production tooling on the P-80, and the tooling itself required a high type of precision. The high speeds of the airplane, which required a very exacting flight article, forced Lockheed to design the tooling with closer tolerances than had been required for the manufacture of any previous airplane.[115]

Although the tooling problems were eventually overcome, they were troublesome. Far more seriously, Lockheed continued to experience difficulties with the engines and other parts for the P-80. Delivery of the engines was slow and often erratic. Through the summer of 1945, the Air Force was forced to accept P-80's without engines or other parts.[116]

In fairness, many of these problems were hardly Lockheed's fault. The engines and other parts that were delayed were not manufactured by Lockheed, but by various other suppliers and

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sub-contractors. As stated above, the extremely high standards of precision the P-80 required to function properly imposed delays on the project. Furthermore, the Air Force's own eagerness for the plane was a major cause of delays. In less than a year, the Air Force had gone from requesting 500 P-80's from Lockheed to wanting over 9,000 of them, necessitating the addition of a second aviation company in the production cycle. Lockheed's President, Robert Gross, stressed these points in a 16 June 1945 letter to Major General K. B. Wolfe, the Chief of Engineering and Procurement at Wright Field:

> In regard to the shortage of parts, Lockheed stated that the company had advised at the time the Army established the existing P-80 schedule that this development might occur. The day that the accelerated schedule was superimposed on the former schedule, Lockheed was automatically placed in a behind-schedule position, and efforts since that date had been an attempt to reduce this handicap.... Primarily, deliveries were behind schedule because of engine and other GFE shortages, and receipt of defective equipment had further complicated deliveries.[117]

Some of the Air Force orders were pared away following the surrender of Nazi Germany. On 25 May 1945, the government canceled 452 of the planes it had ordered from Lockheed, and 1,000 from those ordered from North American.[118] The next day, 26 May 1945, the government canceled the North American order in its entirety.[119] These cancellations did not actually affect Lockheed's delivery schedule, however. For the foreseeable future, Lockheed was still being held to the same demanding delivery schedule for the P-80 through 1946.[120]

Not only did P-80 production labor under a number of handicaps, but the airplane itself still had a great many "bugs" to be worked out. Although the original *Lulu-Belle* led something of a charmed life, flying for a number of years without a serious accident, the other models of the P-80 were not so fortunate. The accidents that resulted in the complete destruction of two of the

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YP-80's and the death of their pilots has already been discussed. To that can be added the disintegration of the original XP-80A, *Gray Ghost*.

On 20 March 1945, *Gray Ghost* took off from Muroc on a routine test flight, with Tony LeVier at the controls. The purpose of the flight was high speed level flight to test a new design on the boundary bleed ducts. While flying at approximately 10,000 feet at a speed of 560 mph, there was a burst of loud noise from the rear of the airplane, which then pitched nose down and began to tumble violently. LeVier was unable to bring the aircraft back under control, and attempted to abandon the plane. This proved easier to decide than to accomplish. The violent maneuvers of the plane alternately tossed LeVier about the cockpit and pinned him inside. Eventually the combination of an inverted airplane, frantic effort and a great deal of luck allowed LeVier to win free of the madly gyrating plane.[121]

Once free of *Gray Ghost*, LeVier was able to open his parachute and try to determine what had happened. As it turned out, the tumbling form of *Gray Ghost* was close to him as he fell, allowing him to observe that the aircraft was missing its entire tail section. LeVier's descent continued to be more exciting than he really wanted, as the combination of a small parachute and strong winds set him to oscillating violently as he descended.[122] As a result of the oscillation, rather than land on his feet, he was slammed horizontally into the desert floor, causing injury to his back. LeVier was forced to wear a back brace while his injuries healed, and was temporarily suspended from flight duty. As a result of his accident, "risky" test flights over Muroc were banned when the ground winds exceeded 25-30 mph.[123] LeVier eventually returned to the P-80 program, and campaigned for larger parachutes![124]

Later examination of the wreckage revealed that *Gray Ghost* had indeed lost her tail. The

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cause was determined to be a faulty turbine wheel in the engine, which had shed bits of itself while operating. Since the turbine spins at many thousands of rpm's, those small bits of loose turbine steel were flung outward at considerable speed, essentially turning them into so many high velocity projectiles. This stream of high velocity steel particles literally cut through the relatively thin aluminum of the rear fuselage, sawing the tail off.[125] Of course, the "how" of such an accident is the easy part. The "why" is usually much more difficult to ascertain.

In this case, the "why" took many months to track down. It was ultimately discovered that the turbine itself had been defective, with impurities that had weakened the whole structure. The "why" of how it had been made that ways was traced to faults in the ingots of steel used by General Electric to manufacture the turbine wheel. The upper half of the steel ingots contained impurities, which rose during the casting process. The solution was simple enough once the problem had been identified - manufacture the turbine wheels only with steel from the lower half of the ingots.[126]

Although LeVier's accident was dramatic, at least he had the benefit of being a trained test pilot, someone who was paid to take risks with experimental aircraft. As the rush to get the P-80 operational continued and production P-80's with unresolved "bugs" began to find their way into the hands of ordinary pilots, the accident rate increased sharply. On 1 July 1945, a P-80A crashed on take-off, killing the pilot. The pilot, 1st Lieutenant Joseph Mandl of the 6th Ferrying Group, who was attempting to take off from Long Beach, California, had aborted two previous take-off tries, and on the third got airborne briefly. The aircraft then stalled, impacted the pavement, skidded into a parking area and crashed into an A-26. It was later determined that Lt. Mandl had his flaps set only to 45 degrees, generating insufficient lift for the heavily-loaded airplane on the

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short runway.[127]

On 2 August 1945, Major Ira B. Jones was ferrying a YP-80A from Wright Field in Ohio to Dallas, Texas for modification work. About 30 minutes into the flight, control of the aircraft was lost, causing a crash and killing the pilot. The plane crashed near Codman Field, Kentucky.[128] By 18 August, 1945, the cause of the accident was determined to be the failure of the elevator actuator, which in turn caused elevator flutter and tail failure. Deprived of its tail, the aircraft crashed. The fix was again relatively simple - install heavy duty actuators for the elevators and trim tabs.[129]

On 6 August 1945, the most serious P-80 accident took place. Major Richard Ira Bong, America's "ace of aces," the top-scoring fighter ace with 40 confirmed kills,was taking a P-80A for an initial acceptance flight. Major Bong scored all of his kills in the Pacific Theater, as part of General Kenney's 5th Air Force, flying Lockheed P-38 Lightning fighters. Major Bong was rotated back to the United States after he achieved his fortieth kill and his only close rival in scoring, Major Thomas McGuire (38 kills) was killed in a crash. It was felt that it would be devastating if America's leading ace was killed in combat, so he was sent home to do war bond drives. Eventually he was assigned to the 412th FG.

Shortly after take-off, Major Bong's aircraft appeared to lose power and crashed to earth. Major Bong was killed instantly.[130] For the first time, the safety record of the P-80 was thrust under public scrutiny. Accidents, even severe ones, are an expected part of the development process for a combat aircraft, as the bugs are worked out. But by the time an aircraft reaches production status, the bugs are assumed to have been largely fixed. Most certainly, the plane should not lose power and crash on a simple take-off - especially with America's most successful

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and decorated pilot at the controls.

As it turned out, Major Bong was a victim of the same problem that had killed Milo Burcham - fuel pump failure. Ironically, he need not have been. After Burcham's accident, all P-80's were equipped with an auxiliary electric fuel pump, in case the primary one malfunctioned.[131] Bong, although informed of the auxiliary pump by the ground crew, apparently neglected to turn it on before take-off. So when the main pump failed and the engine quit, the backup pump which might have saved his life was inoperable.[132]

Successful fighter pilots usually have an aggressive self-confidence that often borders on suicidal. When then Lieutenant Bong was still in training in the United States prior to entering combat, he flew a loop around the center span of the Golden Gate Bridge. This brought him a sharp official reprimand, and a private reputation as a "hot" pilot with great potential. Despite the fact that Bong's death was at least partially the result of pilot error (or perhaps pilot cockiness would be a more accurate term) his accident did point, again, to a serious weakness in the P-80. Because of the publicity surrounding his death, not to mention the irony of it taking place on the same day that the first atomic bomb was dropped on Hiroshima, an order was issued immediately grounding all P-80's until they were declared to be safe to operate.

> Washington directed that no further flying be done on P-80 type aircraft until a thorough investigation and analysis of the causes of the fatal accidents had been conducted and corrective measures had been taken. A report on the probable causes of the accidents was requested, as well as information concerning what corrective measures had been and were being taken to make a more satisfactory job of the P-80. No further flights were to be made from Burbank until the situation was clarified.[133]

When the P-80 program resumed, it would do so at a much more sedate pace, and with a greater

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emphasis on safety. When flight tests of the P-80 resumed at the end of September 1945, the commander of the test unit, at least half seriously, threatened to court martial any pilot who so much as scratched a plane.[134] This eventually enabled Lockheed to correct the various problems with the aircraft, and the P-80 would eventually establish a solid record for dependability and safety.

One final area of consideration of the wartime P-80 program is the attempt to get it into combat. Various Air Force officers had been screaming for P-80's to be used in combat almost as soon as *Lulu-Belle* completed her first flights. With production versions of the P-80 beginning to come off the assembly line in early 1945, plans were made to introduce the plane to combat as soon as possible.

Before beginning this discussion, it is important to point out that there is a world of difference between simply producing planes, and being able to use them effectively in combat. It is a point often overlooked when considering the use of the Me 262, for example. Between 1,200 and 1,400 Me 262's were manufactured during the war, yet it is usually assumed that only incompetence could have been responsible for the fact that only a few hundred entered combat. The distance between the end of the assembly line and a front-line airfield can be a long one, indeed, especially for a radical new airplane such as the Me 262 or P-80.

The obstacles between the production and the effective use of a new type of airplane include such elements as: 1) the time to accumulate a sufficient quantity of the plane to equip (plus spare aircraft) one or more air combat units; 2) the need to *thoroughly* train both flight crew *and* ground crew in the operation and maintenance of the plane; 3) the necessity of developing a useful doctrine for the effective employment of the plane; 4) the need to amass sufficient spare

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parts (including extra engines - an especially important element for the early jets) to keep the machines flying; 5) the time to either create a new organization to fly the plane, or take an existing group and re-equip it with the new plane; 6) the need for the pilots to be sufficiently experienced with the plane to be comfortable with it - this means both that the pilots feel that the plane is safe and dependable, and that they are familiar enough with it to exploit its performance capabilities, and finally; 7) the requirement to relocate the newly-equipped air combat group to a combat theater, with its airplanes, personnel and equipment. Attempting to take short cuts with any of these steps will result in a much less effective combat use of the plane.

An example of seemingly experienced and prepared pilots not being completely familiar with a plane, and thereby crippling its effectiveness, can be seen with the Me 262. The *Luftwaffe* trained many former bomber pilots to fly the machine. This made excellent sense for many reasons. These were often very experienced pilots, as opposed to the raw rookies coming out of the pilot training program. The Me 262 had two engines, which most bombers did but most other fighters did not. Bomber pilots also receive more training in navigation, which was useful with the high speeds of the Me 262. Finally, there were many extra bomber pilots, as the *Luftwaffe* had ceased to build bombers by this stage of the war.

There was one crucial area that was overlooked by this program. Fighter pilots are expected to be aggressive, to seek out and attack the enemy. Bomber pilots, on the other hand, prefer to avoid the enemy, since combat is likely to result in damage or destruction of the bomber. Although the former bomber pilots who flew the Me 262 did learn to fly the plane quickly and well, they lacked the aggression needed to make full use of its capabilities. There are numerous reports of Allied pilots encountering Me 262's that were too well flown to catch, but were

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strangely unaggressive. This behavior could have been corrected, given enough time and training, but both were lacking late in the war in Germany.

In the case of the P-80, the decision was made early in the production process to place the first production models with the 412th Fighter Group.[135] This was a completely logical choice, as the 412th FG had been the unit that received and trained on P-59 Airacomets, America's only previous jet fighter. The 412th was composed of the 29th, 31st and 445th Fighter Squadrons, the 361st Service Group and had the 39th Photo Reconnaissance Squadron (equipped with the reconnaissance version of the P-80, the F-14). The 412th, along with pilots from Wright Field, participated in the Accelerated Service Tests of the P-80A.[136] It was during these tests that Major Bong was killed.

Although the 412th FG was assigned priority in receiving the new P-80As, the various problems Lockheed was having with aircraft deliveries meant that as late as the summer of 1945, the 412th FG has not yet received its full complement of P-80s. In fact, at the time the war ended, the 412th FG had *no* P-80s. A number of pilots from the group had been involved in the Accelerated Service Tests, and several of the first P-80As off the production line had been assigned to the group, but these early P-80As still had a number of potentially serious problems, and so were all eventually given back to Lockheed for corrective work. The 412th FG was instead temporarily assigned P-51 Mustangs to fly, in case they were committed to combat before the P-80As were ready.[137]

Still, prior to the dropping of the atomic bombs and the surrender of Japan, the Air Force plans called for the 412th FG to receive its P-80A's, train on them and deploy to the Pacific Theater by 1 December 1945.[138] Details as to exactly where they would have been based and

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what their mission would have been had not yet been documented. The P-80 had a relatively short combat range, and only the island of Okinawa, the last major island captured from the Japanese, would have been close enough to use as a base for the aircraft. Of course, once portions of the Japanese Home Islands were captured, the P-80 could have been based there as well.

As it turned out, the 412th FG did not receive its full complement of P-80As by 1 December, 1945. A large portion of the responsibility for this was no doubt the confusion created by the end of the war. The government slashed all military equipment contracts almost immediately after Japan's surrender, and the P-80 was no exception. The P-80 actually got off lightly, compared to many other aircraft. At one point, the government had contracted for 6,631 P-80's from Lockheed, plus the aircraft from North American. Despite the cancellation of the North American order and 452 aircraft from the Lockheed order following Germany's surrender, there were still over 6,000 aircraft on order.

Within days of Japan's surrender, the government canceled 1,863 P-80's from contract W33-038 ac-8388, which had been for a total of 2,548 planes.[139] By 5 September 1945, the government had canceled the entire contract.[140] The cancellation of 83 planes from contract W33-038 ac-2527 brought the total of canceled planes to 2,621.[141] Further cancellations (including the cancellation and reinstatement of 120 of an improved version of the P-80) eventually brought the number of P-80s on order by then end of 1945 to 917.[142] Since the Air Force cancelled *all* of the piston-engined fighters on order after VJ Day, this demonstrated the Air Force's high and continuing interest in the aircraft.

This reduction in the orders for P-80s, combined with the grounding order and an

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increased emphasis on safety in the testing program, led to a more measured and thorough development program for the plane, benefiting everyone concerned. This allowed the P-80 to reach it's potential as a combat aircraft without the intense pressure to produce a successful airplane *right now*, without having to accelerate the testing program in ways that proved dangerous, and with plenty of time to teach the pilots all the skills and attitudes they needed to fly this new and unusual mount. Since pilot error was involved in many of the P-80's wartime accidents, this last may well have been the most important benefit of all.

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100. Maj. C.R. Hawks, Chief, Engineering Section, Production Division, Western District, Los Angeles, to Aircraft Projects Section, Engineering Division, Wright Field, 14 February, 1945, ***P-80 Case History.***

101. Inter-Office Memorandum from Lt. Col. J. G. Scarff, Chief, Aircraft Procurement Section, Wright Field, to Capt. E. S. Stewart, Legal Section, Procurement Division, Wright Field, 5 September, 1944, ***P-80 Case History.***

102. McLaren, ***Lockheed P-80***, p. 15.

103. Lockheed Aircraft Corporation to Maj. Gen. K. B. Wolfe, Chief, Procurement and Engineering, Wright Field, 25 January, 1945,; Teletype from Maj. Gen. B.E. Meyers, Deputy Director, Air Technical Service Command, Wright Field, to Lockheed Aircraft Corporation., 31 January, 1945, ***P-80 Case History.***

104. Routing and Record Sheet from Col. B.L. Boatner, Acting Chief, Procurement Division, Wright Field, to Lt. Col. S. W. Bishop, Production Section, Wright Field, 2 January, 1945, ***P-80 Case History.***

105. Letter of Contract W33-038 ac-7717, 19 January, 1945, ***P-80 Case History.***

106. Memorandum from Maj. Gen. O. P. Echols, Assistant Chief, Air Staff, Material and Service, Washington, to Commanding General, Army Air Forces, Washington, 31 March, 1945,

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P-80 Case History.

107. Lockheed Aircraft Corporation to Maj. Gen. K. B. Wolfe, Chief, Procurement and Engineering, Wright Field, 25 January, 1945,; Teletype from Maj. Gen. B. E. Meyers, Deputy Director, Air Technical Service Command, Wright Field, to Lockheed Corporation, 31 January, 1945, ***P-80 Case History.***

108. Ibid.

109. Lockheed Aircraft Corporation to Maj. Gen. K. B. Wolfe, Chief, Procurement and Engineering, Wright Field, 25 January, 1945, ***P-80 Case History.***

110. Telegram from Maj. R. E. Hunt, Contract Officer, Wright Field, to Lockheed Aircraft Corporation, 8 May, 1945, ***P-80 Case History.***

111. Routing and Record Sheet from Brig. Gen. P. W. Timberlake, Deputy Chief of Air Staff, Washington, to Assistant Chief of Air Staff, Material and Service, Washington, 30 January, 1945, ***P-80 Case History.***

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113. Inter-Office Memorandum from Capt. J. H. Young, Fighter Branch, Procurement Division, Wright Field to Maj. G. H. Selvin, Fighter Branch, Procurement Division, Wright Field, January 4, 1945 ***P-80 Case History.***

114. Ethell and Price, ***World War II Fighting Jets***, pp. 149-165.

115. Memorandum from Maj. Gen. O. P. Echols, Assistant Chief, Air Staff, Materials and Service, Washington, to Commanding General, Army Air Forces, Washington, 31 March, 1945, ***P-80 Case History.***

116. Mr. Robert Gross, President, Lockheed Aircraft Corporation, to Maj. Gen. K. B. Wolfe, Chief, Engineering and Procurement, Wright Field, 16 June, 1945, ***P-80 Case History.***

117. Ibid.

118. Technical Instruction 2145, Addendum 32, 25 May, 1945, ***P-80 Case History.***

119. Telegram from 1st Lt. W. N. Howell, Contract Officer, Wright Field, to North American Aviation, Inc., Kansas City, 26 May, 1945, ***P-80 Case History.***

120. Telegram from Maj. R. E. Hunt, Contract Officer, Wright Field, to Lockheed Aircraft Corporation, 25 May, 1945, ***P-80 Case History.***

121. Wooldridge, ***The P-80,*** p. 46.

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122. Ibid.

123. Ibid.

124. Pace, ***Skunk Works***, pp. 51-2.

125. Maj. C. R. Hawks, Chief, Engineering Section, Production Division, Western District, Los Angeles, to Service Engineering Section, Aircraft Projects, Engineering Division, Wright Field, 24 March, 1945, ***P-80 Case History.***

126. Wooldridge, ***The P-80***, p. 46.

127. McLaren, ***Lockheed P-80***, p. 22.

128. Teletype from Col. M. F. Cooper, Chief, Aircraft Projects Section, Engineering Division, Wright Field, to Maj. J. K. Bussey, Aircraft Projects Branch, Assistant Chief, Air Staff, Materials and Supply, Washington, 3 August, 1945, ***P-80 Case History.***

129. Teletype from Col. G. E. Price, Procurement Division, Wright Field, to Col. H. G. Bunker, Office of Assistant Chief, Air Staff, Materials and Supply, Washington, 17 August, 1945, ***P-80 Case History.***

130. Maj. C.R. Hawks, Chief, Engineering Section, Production Division, Western District, Los Angeles, to Service Engineering Section, Aircraft Projects, Engineering Division, Wright Field, 8 August, 1945, ***P-80 Case History.***

131. Ethell and Price, ***World War II Fighting Jets***, p. 176.

132. Wooldridge, ***The P-80***, p. 48.

133. Teletype from Army Air Force, Washington, to Air Technical Service Command, Wright Field, 7 August, 1945, ***P-80 Case History.***

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135. Col. J. F. Phillips, Chief, Materials Division, Office of the Assistant Chief, Air Staff, Material and Supply, Washington, to Engineering Division, Wright Field, 14 November, 1944, ***P-80 Case History.***

136. McLaren, ***Lockheed P-80***, pp. 17-8.

137. Ibid., pp. 25-6.

138. Memorandum from Brig. Gen. W. F. McKee, Acting Assistant Chief, Air Staff, Operations, Commitments and Requirements, Washington, to Chief, Air Staff, Washington, 8 June, 1945, ***P-80 Case History.***

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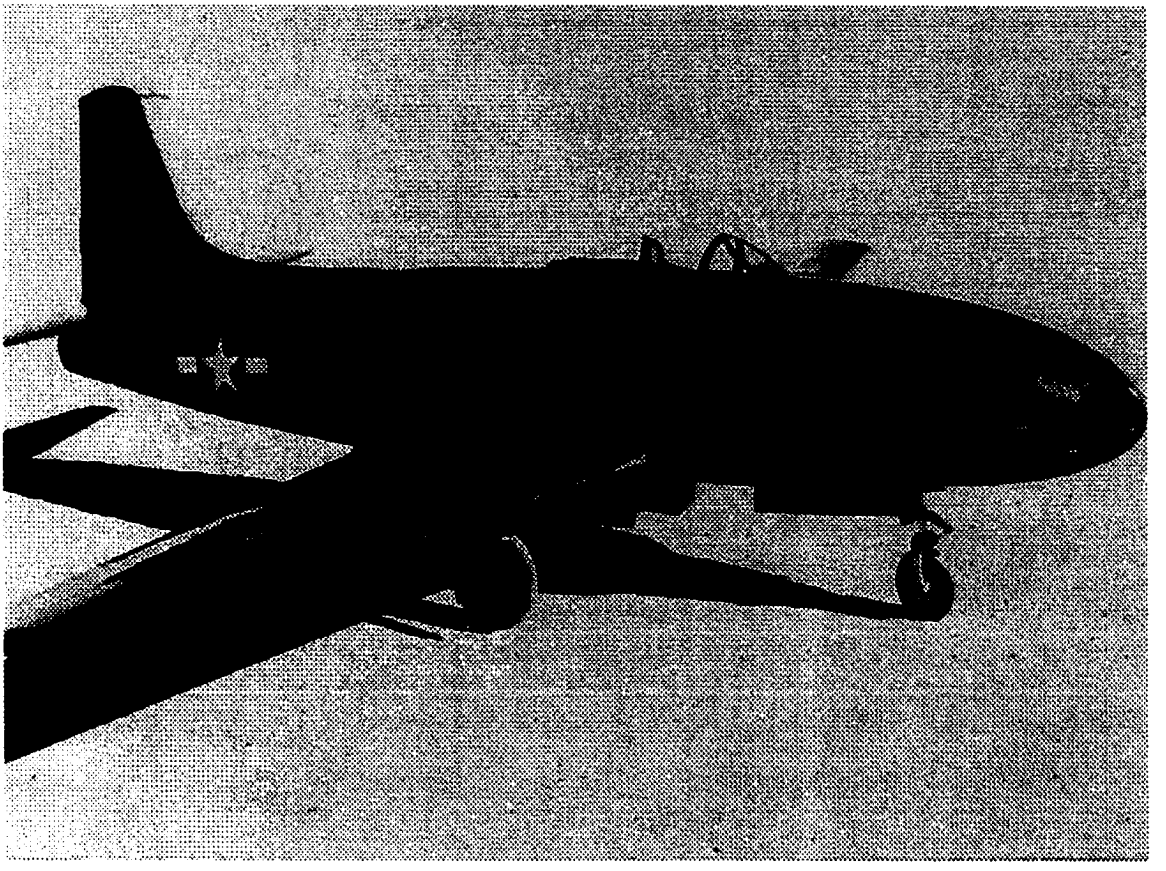
139. Telegram Termination Notice to Contract W33-038 ac-8388, 13 August, 1945, ***P-80 Case History.***

140. Telegram Termination Notice to Contract W33-038 ac-8388, 5 September, 1945, ***P-80 Case History.***

141. Telegram Termination Notice to Contract W33-038 ac-2527, 5 September, 1945, ***P-80 Case History.***

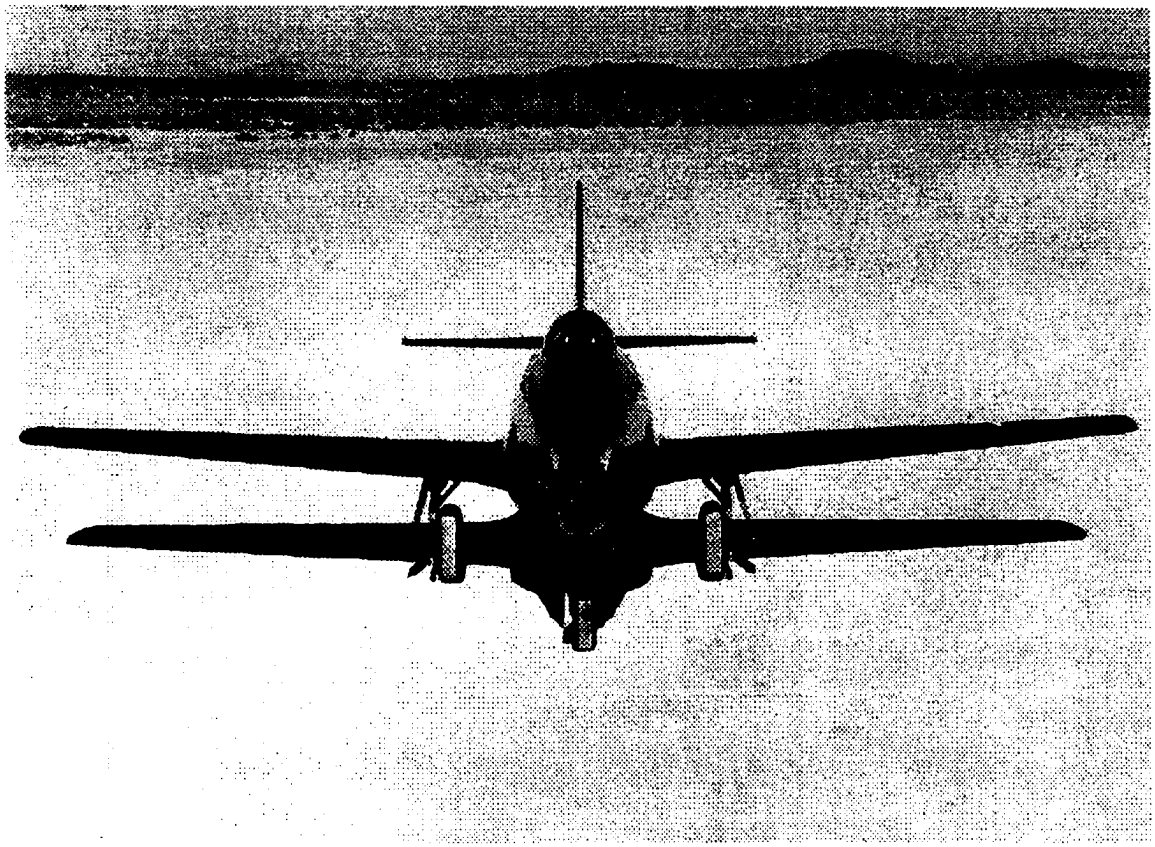
142. Technical Instruction 2145, Addendum 46, 31 January, 1946, ***P-80 Case History***.

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The original XP-80 prototype, *Lulu-Belle*, during her testing at Muroc. The attractive dark green glossy finish is noticeable. Photo credited to September 1944 issue of ***Impact***, dated 2 August 1944. (National Archives, Photographic Division, Box 2029, Number 30043)

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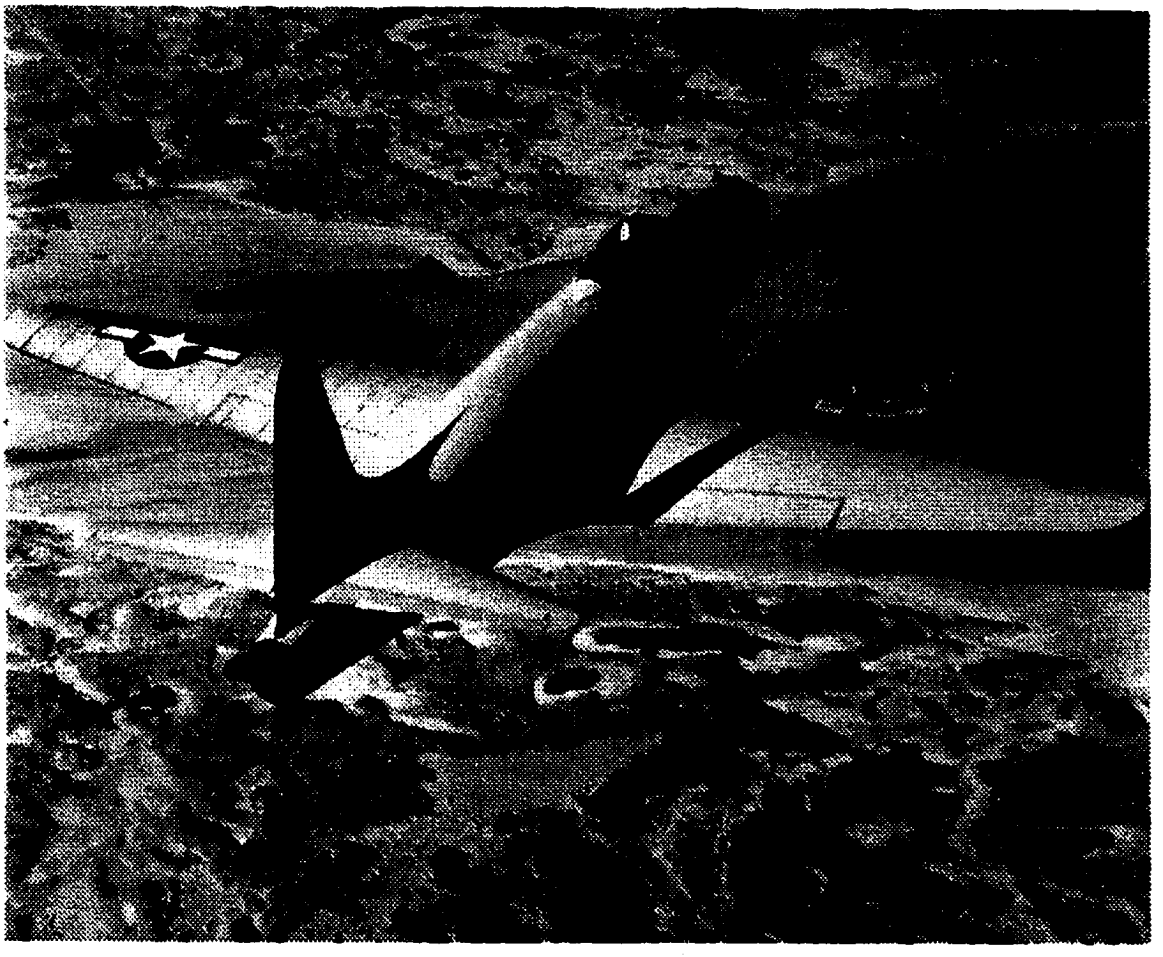
Lulu-Belle in a head on view. The extremely clean lines of the design are obvious from this vantage. Photo credited to September 1944 issue of ***Impact***, dated 2 August 1944. (National Archives, Photographic Division, Box 2029, Number 30042)

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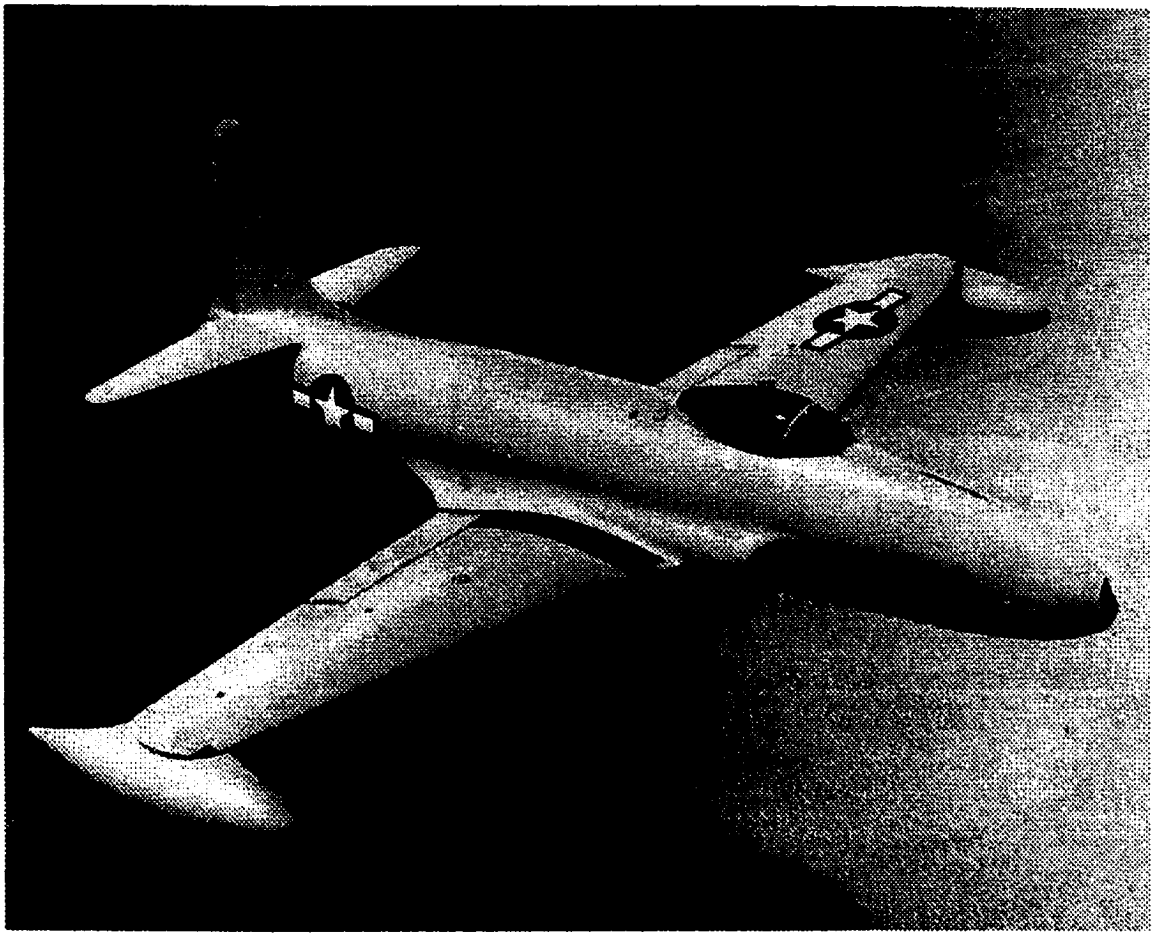
The XP-80A, *Gray Ghost*, on the ground at Muroc. Photo dated 25 July 1945. (National Archives, Photographic Division, Box 2029, Number 30047)

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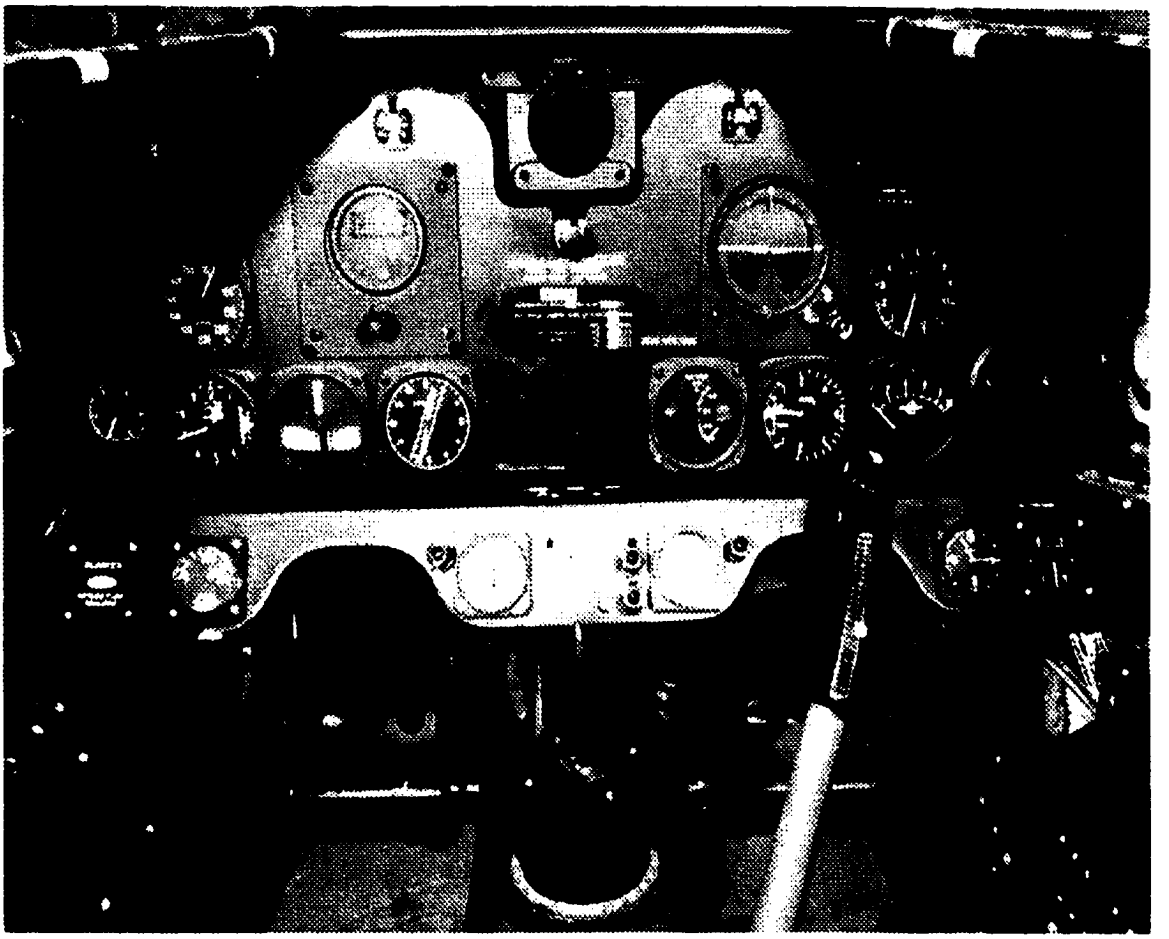
The XP-80A *Gray Ghost* in flight over Muroc. Several interesting elements are present in this photograph. The distortion from the hot exhaust gasses is visible to the rear of the tail pipe. The left wing has a series of airflow strips attached to it. These are small, flexible strips that provide visible evidence of any disturbances in the airflow over a surface, and were often used on test aircraft. Also, a mock "battleship" target may be observed just above the right wing of the plane. Photo credited to February 1945 issue of ***Impact***, dated 8 January 1945. (National Archives, Photographic Division, Box 2030, Number 30076)

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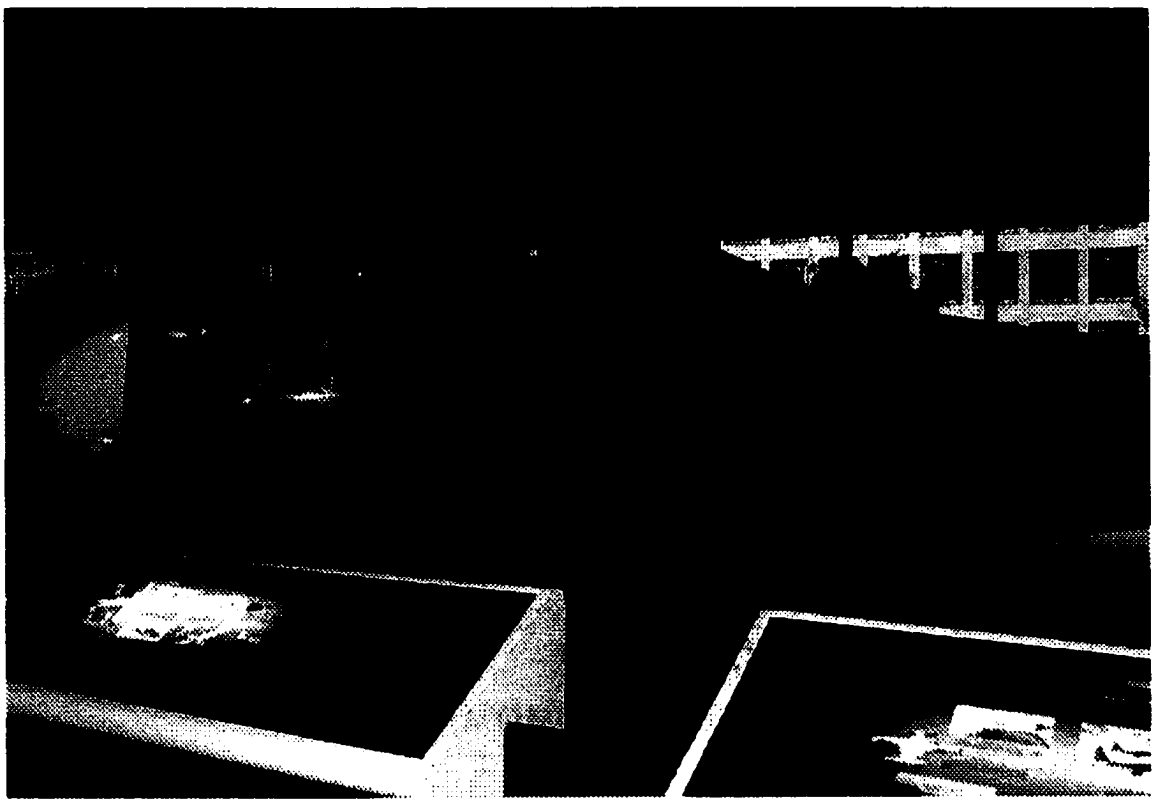
One of the first batch of the production model of the new P-80A-1. The overall light gray finish, the factory applied name "Shooting Star", and the new wing tip fuel tanks are all notable in this shot. Photo credited to Press Release "Jet Fighter" in January 1946 issue of ***Air Force***, dated 23 July 1945. (National Archives, Photographic Division, Box 2030, Number 30079)

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The business office of a P-80. The instrument panel of a P-80A-1. Note the relative simplicity of the instrumentation compared to today's jets. Photo credited to February 1945 issue of ***Impact***, dated February 1945. (National Archives, Photographic Division, Box 2030, Number 30181)

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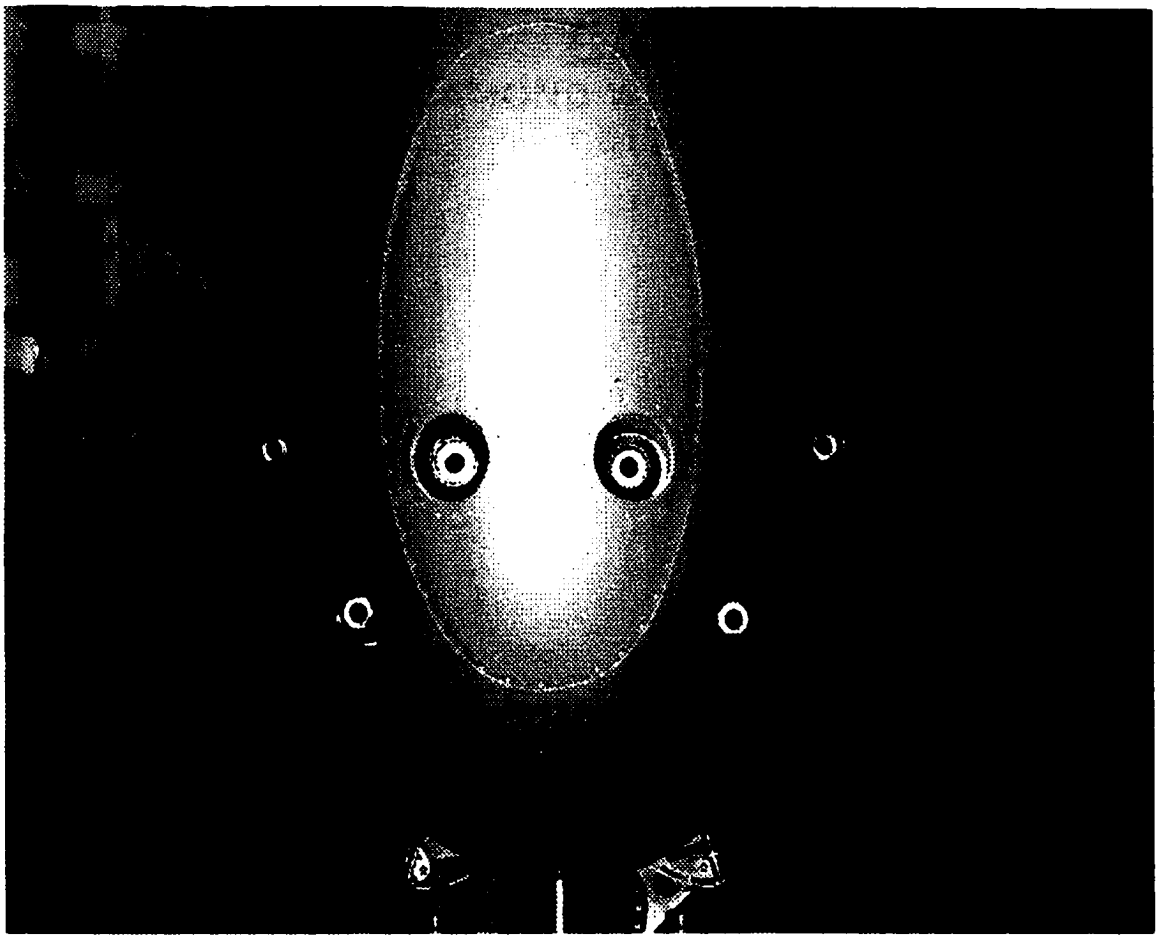
The original XP-80, *Lulu-Belle*, is now on permanent display in the National Air and Space Museum of the Smithsonian institution. The aircraft has been lovingly restored to pristine condition, and serves as a reminder of America's entry into the jet age. *Lulu-Belle* is displayed alongside a contemporary, a Me 262. (Author's photo)

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The sleek menace of *Lulu-Belle* is apparent in this view. (Author's photo)

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The business end of *Lulu-Belle*. The muzzles of the six .50 caliber machine guns are clearly visible. The close grouping of the guns, and thus the heavy concentration of firepower, is obvious in this shot. (Author's photo)

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"The P-84 is regarded by the Army Air Forces as the most advanced plane of its type now in production in this Country."
From a statement issued by Republic Aviation[1]

Chapter 5
Additional American Wartime Jet Fighter Developments

The P-59 Airacomet and the P-80 Shooting Star were the American jet fighters that achieved production status during the Second World War, but they were by no means America's only wartime jet fighter projects. There were, in addition to these two, a number of interesting and unusual jet designs, including two that would go on to long and successful careers with the postwar Air Force. Only Nazi Germany was more prolific in its pursuit of jet propulsion.

The United States, in addition to the P-59 and P-80, ordered at least five jet fighter designs during the war. These include the Northrop XP-79B flying wing, the Convair XP-81 jet/turboprop hybrid, the Bell XP-83, a scaled up long-range version of the P-59, the Republic XP-84 interceptor and the North American XP-86 interceptor. Along with these may be considered the McDonnell XP-67 which, although a piston engined fighter, utilized superchargers along with its twin engines to provide a form of jet exhaust to increase its speed. In addition, there was a concept that originated during the war, the internally stowed, or 'parasite' fighter. This idea was deferred until after the war, and produced a very unusual looking airplane, the XF-85 Goblin.

Of these designs, four - the XP-67, the XP-79B, the XP-81 and the XP-83 - were actually produced as flying prototypes during the war, although only the XP-67 and XP-83 were extensively tested during the conflict. The other two models, the XP-79B and the XP-81,

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although completed during the war, were not tested until after it was over. The XP-84 and XP-86 were still in the design/construction phase when the war ended, although the first XP-84 was finished a few months later and flew in early 1946. The XP-86 took longer to finish, largely because the design was drastically altered partway through the process, to take advantage of performance enhancements available from captured German records and equipment.

The discussion of America's wartime jet projects will begin with a machine conceived during the war but produced only after it ended. Because of its early origin, the XF-85 appears only briefly in this chapter, and then will be dealt with in more depth in a subsequent chapter. Before the United States entered the war, in the dark days of 1940 and early 1941, it looked as though a German victory in Europe was a distinct possibility. Only Britain still resisted the Nazis, and the British seemed to many Americans to be woefully unprepared to stop the might of the *Wehrmacht*. American military planners were forced to consider the unpalatable idea that it might be necessary to wage war against a German-dominated Europe without access to any European bases. This meant that the Army Air Force was forced to consider the idea of bombing Europe from bases in North America.

This unpleasant state of affairs produced several designs for extremely large, extremely long range aircraft to conduct such bombing missions. One such design was the Convair XB-36.[2] The XB-36 was an enormous aircraft, powered by six huge piston engines on the rear edges of the wings driving pusher propellers.[3] The aircraft was so large that the wings were nearly 6 feet thick, and contained access tubes that allowed the crew to reach and service the engines while in-flight. As events turned out, England did not fall, and the need for a trans-Atlantic bomber faded. The XB-36 was put on the shelf, to await the coming of the Cold War, when the need for super-

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long range bombers once again emerged. Given a second lease on life, the plane was built as the B-36 Peacemaker, the world's first true intercontinental bomber.

When the XB-36 was first conceived, both the need for and the impossibility of using some sort of escort fighter was recognized by the Air Force. Even the longest-legged of the late-war piston engined fighters, the P-51D Mustang and the P-47N Thunderbolt, would have had barely a fraction of the endurance necessary for such a trans-oceanic mission. Then some bright fellow had an inspired idea (or more accurately, resurrected an earlier idea). If you need fighter escort, and the fighters cannot make it on their own, why not bring one with you? Thus was born (or rather, reborn) the idea of the 'internally stowed' or 'parasite' fighter.

As mentioned, this idea was not in fact original to the XB-36 program. During the 1930s the Soviets had developed a system for carrying up to five parasite fighters on a TB-3 bomber, and actually used this arrangement in combat in the early stages of the German invasion of the Soviet Union in the summer of 1941.[4] The idea had even been used in the United States before, although by the Navy and not the Air Force. In the late 1930s the Navy had kept an entire squadron of the small Curtiss F9C Sparrowhawk fighters aboard two rigid airships, the *Akron* and the *Macon*. Both the *Akron* and *Macon* were lost to accidents and the program was abandoned by the Navy.[5]

Now the Air Force seized upon the idea of the parasite fighter to complement the XB-36. Why not design a small, lightweight fighter that could be carried internally by a sufficiently large aircraft, launched when needed, and then recovered by the parent aircraft after the action was over? The idea was never put to the test during the war, for when the need for the XB-36 faded, so did the concept of the parasite fighter. When the B-36 was put back into development later in

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the decade, the idea of the parasite fighter was pulled out and dusted off, resulting in the creation of the XF-85 Goblin, surely one of the strangest-looking fighters ever to fly.

The first of the additional jet fighters actually constructed during the war was the McDonnell XP-67. This plane had its origins in the Army Air Force's 18 December 1939 "Request for Data R-40C," which asked companies to submit designs for unconventional fighters powered by Pratt & Whitney X-1800-A3G engines.[6] The McDonnell Aircraft Company, which had been formed in July 1939, decided to use this proposal as the basis for their first military aircraft design. The original McDonnell design called for the engine to be buried in the fuselage behind the pilot. This engine would power a pair of pusher propellers mounted in the wings via a pair of right-angle jointed extension shafts. This struck the Air Force as overly complicated and potentially dangerous, and they did not select the design for testing, although they allowed McDonnell to continue working on it.[7]

The revised design, of more conventional construction, was intended to be a new type of plane for the Air Force - a heavy bomber destroyer. The Air Force was placing great emphasis on the use of large, four-engined strategic bombers, and they considered that they might have a need to combat similar types of bomber aircraft in the future. For that reason, the XP-67 was intended to be armed with no less than six 37 mm cannon, each with 270 rounds of ammunition.[8]

The XP-67 was a very intriguing design. It was very streamlined, with a rounded, almost melted look. It was powered by two Continental XI-1430-17/19 engines mounted in large pods on the wings. The engines drove four bladed propellers, but also used a novel feature to increase the aircraft's speed. The engines used large turbo-superchargers, which were becoming increasingly common on piston-engined planes. These superchargers were not used to enhance

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the piston engine's performance, but rather ran off of exhaust gases generated by the main engines. They vented the highly compressed air they produced out the rear of the engine nacelles to add thrust and increase the aircraft's speed.[9] Thus while not a solely jet powered plane, the XP-67 did make use of the jet principle for power.

Due to its flattened construction and smooth, flowing lines, the XP-67 was known as the "Bat" or "Moonbat," and was also called the "Bomber Destroyer."[10] The Air Force had ordered two prototypes, and the first was completed on 1 December 1943. It made its first test flight on 6 January 1944.[11] Because the engines delivered only about 1,000 of the promised 1,350 horsepower, the XP-67 was rather underpowered. A major consequence of this was poor take-off characteristics, in particular an extremely long take-off run. Otherwise the flight characteristics were considered to be excellent.[12]

The engines of the XP-67 continued to be troublesome throughout the test program, repeatedly breaking down and catching fire. During a flight on 6 September 1944, just before the plane was to undergo its official Air Force performance tests, the starboard engine caught fire, forcing an emergency landing. Although the plane was landed safely and the pilot unharmed, the fire could not be extinguished before it had destroyed the plane.[13]

The second prototype of the XP-67 had been intended to be powered by two more powerful Rolls Royce Merlin piston engines and two small jet engines in place of the superchargers. Construction of this machine had been halted when it was only 15 percent complete. With the first prototype destroyed and the second one unfinished, the entire XP-67 program was canceled in October 1944.[14]

During the war, the American aviation industry produced a large number of outstanding

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combat aircraft, often in enormous numbers. As a rule, however, American aviation was not tremendously innovative, preferring to concentrate on proven concepts rather than risk the failure of some promising but experimental project. Some of the rare exceptions to this attitude were the designs submitted in response to R-40C, the same requirement that produced the XP-67. Although the XP-67 was not selected by the Air Force for development under these specifications, three other designs were. All three of these designs attempted new, unusual, and innovative concepts. The Vultee XP-54 Swoose Goose, the Curtiss XP-55 Ascender and the Northrop XP-56 Black Bullet were all rather radical airplanes by American standards, with impressive performance. Significantly, perhaps, none of them were selected for production.[15]

This same conservatism can be seen in the various American jet projects. While German aviation was experimenting with fixed, variable and forward swept wings, flying wings, rocket propulsion, pulse jets, ram jets, delta wings and other forward looking concepts, most of American aviation simply added jet engines to otherwise conventional designs. Although Kelly Johnson of Lockheed was capable of great creativity and innovation, as can be seen by his L-133 canard jet design, the wartime production demands on his company limited what he was allowed to create. The one American designer who matched the German interest in new concepts was John 'Jack' Knudsen Northrop, head of Northrop Aircraft Inc. Northrop, like the German designers Alexander Lippisch and the Horten brothers, was fascinated by the concept of the flying wing. He was convinced that the most efficient form of flying machine was that of pure wing, with no other surfaces to mar the airflow.[16]

Beginning in 1928, Jack Northrop began to experiment with the flying wing concept. In the fall of 1942 Northrop presented the Air Force with a design for a fighter that incorporated a

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number of new and radical concepts. Not only was it a flying wing, like many of his designs, but it was also to be powered by a liquid-fueled Aerojet rocket engine, much like the German Me 163. Further deviating from convention, the plane placed the pilot in a prone position in the front center of the wing, looking out a large clear canopy. The pilot lay on his stomach on a padded platform, with his head towards the front of the aircraft. This was done to increase the 'G' tolerance of the pilot. Violent aerial maneuvers induce stress on both aircraft and pilot, measured as multiples of the force of gravity, or G's. As a pilot is subjected to increased G-forces, these pressures eventually affect the pilot's circulatory system. Specifically, they inhibit the flow of blood to the brain, causing a loss of vision and eventually loss of consciousness. In a seated position, a pilot can pull 5 to 6 G's before loosing consciousness. Studies were conducted that showed that a prone position increased a pilot's G tolerance considerably, to 9 to 10 G's. However, the limitations of the prone position (limited arm movement range, awkward neck angle, limited vision range) combined to prevent any aircraft designer from successfully using prone position piloting, although a number made the attempt.

Northrup's plane lacked conventional rudders for steering, replacing them with wingtip bellows. These were essentially tubes attached to the wingtips, through which air flowed. By altering the airflow through the bellows by the use of flaps and vanes, yaw could be induced and the heading of the plane could be altered. The plane also used a four-point landing gear, rather than the traditional three. Not content with all of these innovations, Jack Northrop intended the plane to be built entirely of magnesium, for a combination of lightness and strength.[17]

The Air Force was impressed enough to order three prototype machines in January 1943 for evaluation. These machines were given the designation XP-79. Northrop wanted to produce

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the planes, but was unable to handle the work themselves, as they lacked the workforce and shop space to do the work in addition to their other projects. They therefore sub-contracted the work to the Avion Shop, and assumed a supervisory role in the project.[18]

Several months after the prototypes were ordered, the Air Force decided to have the third machine converted from rocket propulsion to use axial flow jet engines. These two Westinghouse 19-B engines produced 1,150 pounds of thrust each, for a total of 2,300 pounds of thrust. This plane was redesignated the XP-79B.[19]

There were numerous problems with the construction of these aircraft. One of the most severe arose from the decision to use magnesium. This material had not previously been used for such construction, and was much stronger than the usual aluminum. Its structural strength required the development of entirely new construction techniques, including the best way to weld magnesium.[20] Further difficulty arose from the selection of Avion to do the actual construction. Government reports in June 1944 indicated that Avion had "undesirable shop practices, and low shop morale."[21] This, combined with Aerojet's difficulties with its rocket motor, eventually led to the cancellation of the first two XP-79 prototypes, and a concentration on the third machine, the XP-79B, to be completed at Northrop facilities.[22]

The use of magnesium in the construction of the XP-79B created an extremely strong airframe. During the construction period, some thought was given to the idea of using the strength of the plane directly in combat. This would be done by outfitting the aircraft to attack bombers physically, by ramming them in an attempt to shear off portions of the enemy plane.[23] Ramming attacks had been used by other aerial combatants, with mixed success. The Russians used the tactic with some success during the early stages of the German invasion of Russia, and

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the *Luftwaffe* had appropriated the tactic for its *Rammjaeger* squadrons. In any event, the idea was not pursued beyond the discussion stage.

The XP-79B was completed and delivered to the Air Force at Muroc in June 1945. It then underwent a series of ground tests before being ready for flight testing. The taxi tests gave considerable problems, as the tires kept blowing out during high speed taxi runs.[24] Finally, on 12 September 1945, the XP-79B took off for its first flight test. Everything proceeded normally for the first fourteen minutes, but then tragedy struck. The plane was observed to go into a slow roll, from which it did not recover. It was later theorized that the ailerons had jammed somehow. Eventually the pilot baled out of the stricken machine, but he was struck by the rolling aircraft and was unable to open his parachute. The XP-79B crashed into the desert floor. The crash produced a fire, and magnesium burns very enthusiastically, so the entire aircraft was consumed by flames.[25]

The Air Force decided that there was little incentive to pursue the project at this point, and the remaining elements of the contract were terminated. Jack Northrop would continue his efforts to develop a flying wing, culminating in the late 1940s with the B-49 strategic bomber. The B-49 was a flying wing bomber, originally designated the XB-35 and designed to compete for the same inter-continental bombing mission as the XB-36. The B-49 replaced the XB-35's piston engines with jet engines to create a giant jet-powered boomerang.

The Consolidated Vultee XP-81 was an attempt to overcome one of the principle limitations of the early generations of jet engines - extremely limited range. Early jets were rather inefficient powerplants compared to the most developed piston engines, and they consumed fuel in enormous quantities. So the question arose - if your long-range bombers were likely to

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encounter jet fighters attempting to shoot them down, and the jet fighters currently in existence or being developed lacked the range to travel with the bombers, how do you protect the bombers? Both Consolidated Vultee and Bell attempted to solve this problem, using different methods.

Consolidated Vultee's solution to the problem of range vs. performance was to attempt to marry two different types of propulsion. The XP-81 was designed to have a General Electric T-100 gas turbine engine driving a propeller in the nose (a turbo-prop, in modern terms) and a GE I-40 jet engine in the rear.[26] The jet engine drew its airflow from two intakes on the upper fuselage, and the exhaust gases exited the tail. The idea behind this arrangement was to have the plane do most of its flying using only the turbo-prop engine, with the jet engine used for take-offs, climbing and combat. This would provide the endurance of a piston engine combined with the speed of a jet.[27]

The Air Force thought enough of the idea to order two X prototypes on 11 February 1944. The airplane, along with the I-40 jet engine, was completed in early 1945, but the T-100 engine was not ready yet. It was decided to proceed with testing using a conventional piston engine until the T-100 was available. The nose section of a P-51 Mustang, with its Rolls Royce Merlin engine was adapted to the XP-81.[28] Fortunately, no major structural modifications were required for this change. The XP-81 was delivered to Muroc, and prepared to make its first flight on 11 February 1945. Unlike the experience of many of the early jets, the first flight of the XP-81 was uneventful.[29]

The XP-81 was a large but graceful looking airplane, and displayed generally very good flying characteristics. Since the Merlin engine had considerably less power than the T-100 was expected to have, performance figures were not considered important in these early tests.

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> Sine the TG-100 power plant was not available at the time the experimental airplane was completed, a Merlin V-1650-7 was substituted. Fortunately, no change of basic structure was entailed thereby. This step was taken only as a stop-gap measure to allow the airplane to be flown for the purpose of checking its stability and control characteristics, its general operation, and to gain experience with the I-40 turbine. Its performance with the Merlin is considerably less than with the TG-100 due to the added weight, the lower horsepower, and the aerodynamic penalties arising from the improvisations.
> Weight added=954 Lbs. Total (567 Lbs. Engine, 380 Lbs. Ballast)
> Horsepower lost=960 BHP for take-Off at Sea Level
> 1720 BHP for Top Speed at Sea Level [30]

The tests were successful enough, however, for the Air Force to order an additional thirteen YP-81 pre-production models.[31] Eventually, the XP-81 was returned to Consolidated Vultee to have the now finished T-100 engine installed.[32]

With the T-100 now installed, the XP-81 resumed test flights on 21 December 1945. The T-100 engine turned out to be a major disappointment. It was anticipated that the T-100 would provide an estimated 2,300 hp, plus 600 pounds of additional thrust from the jet exhaust. Instead, the engine only developed about 1,650 hp, just 200 more than the Merlin engine.[33] Although Consolidated Vultee had optimistic predictions for the increase in performance of the XP-81 with the new T-100 engine, in reality there was virtually no difference in performance between the Merlin and T-100 engines.[34]

The failure of the plane to achieve the performance predicted by the manufacturer, plus the massive budget cuts and diminished expectations immediately following the war meant that the XP-81 was canceled by the Air Force, although Consolidated Vultee did build the two X prototypes and the thirteen Y machines.[35] Although its full performance was not tested, it is likely that the XP-81 would have done what it was designed to - fly distances greater than other current

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jet fighters and fight at jet speeds at the end of the flight. Despite being capable of performing the mission requested by the Air force and for which it was designed, lack of interest in the finished product relegated the XP-81 to the sidelines.[36]

This was not the only American attempt to marry the two forms of propulsion. The other aircraft was developed for the U.S. Navy, the Ryan FR-1 Fireball. Unlike the XP-81, the FR-1 was actually placed in production, although in limited numbers (703 ordered, 66 delivered before the project was canceled on VJ Day). The design of the FR-1 was such that the jet engine in the tail was not obvious to a casual observer. This gave rise to one of the favorite tricks of FR-1 pilots. They would pull alongside a training aircraft, then shut down the piston engine in the nose and feather the prop (turn the blades 90 degrees, so they presented minimal resistance to the wind). Operating on the (largely invisible) jet engine alone, they would then pull away from the startled pilot in the other aircraft, leaving him to wonder how a plane with no engine operating could not only fly but overtake him.[37]

The XP-81's fate awaited the other attempt to produce a very long range jet fighter, the Bell XP-83. Drawing heavily on Bell's experience with the P-59 project, the XP-83 was in many respects a scaled up version of the P-59. The overall layout was very similar, with mid-mounted wings and twin jet engines mounted centered on lower sides of the fuselage. One of the most important lessons of the P-59 was the need for as much power from the engines as possible. So while the P-59 used two I-16 engines of 1,600 pounds thrust, the XP-83 used two J33 engines with almost 4,000 pounds of thrust each.[38]

That power was needed, for the XP-83 was enormous. At the beginning of the Second World War, the trend in aircraft design had been for small, streamlined aircraft, such as the

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Messerschmitt Bf 109, Supermarine Spitfire and Mitsubishi Zero. During the war it was discovered that fighters need not be petite to be effective. The largest, heaviest, and one of the deadliest single seat piston-engined fighter of the war was Republic's P-47 Thunderbolt, known to its pilots as the "Jug" or "Juggernaut." American pilots nicknamed it the "Jug," because they thought its massive fuselage looked like a milk jug. When the plane first deployed to England, British pilots thought "Jug" was short for "Juggernaut," a large, powerful and unstoppable force. Both descriptions were quite accurate.[39]

A comparison between the P-47 and the XP-83 will serve to indicate the extreme size of the latter plane. The P-47D had a wingspan of 40 feet 9 inches, a length of 36 feet 2 inches, an empty weight of 10,700 pound and a fully loaded weight of 17,500 pounds.[40] The XP-83, a single seat fighter like the P-47, had a wingspan of 53 feet, a length of 45 feet, an empty weight of 14,105 pounds and a fully loaded weight of 27,500 pounds.[41] A great deal of that loaded weight was fuel, as the fuselage was essentially a large fuel tank. (For comparison purposes, the P-80 had a wingspan of 39 feet, a length of 34 feet 6 inches, an empty weight of 8,240 pounds and a fully loaded weight of 15,336 pounds.)[42]

Bell began work on the XP-83 in March 1944, and a government contract for two X prototypes was received on 31 July 1944.[43] The first XP-83 made its initial flight on 25 February 1945.[44] No major problems were encountered. Performance was adequate but not spectacular, as could be predicted from the enormous size of the beast. As the plane offered no significant improvement over existing jet planes, and the need for an extremely long-ranged jet fighter had virtually disappeared by this point, only the two prototypes were completed, and no further work was done with this behemoth.[45]

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The other two American wartime jet designs were ones that did not produce finished examples during the conflict, although these planes went on to have long and distinguished careers in both American and foreign air forces. These planes were the Republic XP-84 Thunderjet and the North American XP-86 Sabre. Both aircraft were initiated in response to official Air Force General Operations Requirements for a new jet fighter with demanding performance characteristics, although the XP-86 came to these requirements in a somewhat roundabout fashion.

The new Air Force fighter requirements were first issued on 15 July 1944. By this point, the Air Force had at least some experience with jet fighters from the P-59 and XP-80. These requirements demanded what was then top-of-the-line performance from a jet fighter. The original requirements were:

> Military characteristics of dayfighter aircraft approved 15 July 1944 revoked all previous requirements. Aircraft was to "fulfill all functions of a day fighter, including bombardment escort, interceptor, low level attack and bombing missions." Primary mission was "destruction of hostile aircraft in flight"; secondary mission was "attack hostile ground or waterborne installation by employment of gunfire and/or other destructive agents." Required high speed performance was 425 mph at sea level and 500 mph at 35,000 feet. Required combat radius of action was 750 miles. If performance beyond original requirements could be realized, emphasis was to be placed first on extending combat radius, and second, on increasing speed. Requirements included provision for at least six machine guns of not less than .50 cal., at least three bomb suspension points (or shackles), and at least eight rockets. Ease of maintenance was to receive primary consideration.[46]

These requirements were updated on 11 September 1944 to include the following: top speed of 600 mph, combat radius of 850 miles and an armament of six .60 caliber or eight .50 caliber machine guns.[47] Added to this was the Air Force's desire that the fighter use the newly developed

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General Electric TG-180 axial flow jet engine, which was thought to be superior in performance to the I-40 engine.[48] In addition, the TG-180 was to be used in a new fashion. The engine was to be located in the fuselage, as with the P-80, but the air intake was to be in the nose of the plane, rather than along the sides of the fuselage, with the exit in the tail. This would create a virtually straight airflow, and hopefully better aerodynamics and higher performance.[49]

On 2 November 1944, the Republic Aviation Corporation submitted a proposal to meet these characteristics. Republic would construct three prototype aircraft, with the third one to incorporate any changes necessitated by tests and inspections of the earlier machines.[50] Republic, formerly the Seversky Aircraft Corporation, had been founded by a Russian immigrant, Alexander De Seversky. They had produced a series of increasingly larger and more powerful fighter designs, culminating in the massive and rugged P-47 Thunderbolt. The P-47 was well-loved by its pilots for its ability to absorb battle damage and still return home. P-47s occasionally returned from missions with gaping holes in the airframe, one or more cylinders shot away from the engine, and once even missing four feet of one wing![51] However, by late in the war, the Air Force had expressed a clear preference for the primary rival of the P-47, the P-51 Mustang.[52] Republic produced only the P-47, and with the future of this plane increasingly uncertain, urgently needed a replacement. This new jet fighter was to be Republic's ticket into the jet age. Republic's design was accepted, and the project given the designation MX-578, and the plane the XP-84.[53]

The XP-84 was unusual in that the Air Force not only provided performance parameters, but also specific information on the construction of the aircraft. As stated in the F-84 Case History, "The F-84, then, was created as a specific design problem instead of on the more commonly used competitive-bid contract method."[54] In addition to the very detailed

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specifications for the project, there was no real effort to solicit proposals from several firms, as was the standard Air Force practice.

From the very beginning of the project, problems were encountered. Negotiations between Republic and the Air Force quickly produced a consensus that the Air Force requirements were too demanding for current technology.[55] Given the power limits of the proposed engine, something had to give. The plane simply could not have the specified performance with the stipulated engine and still be within listed weight restrictions. The Air Force agreed to relax the weight restrictions (not the last time this would happen during the life of the P-84), reduce the armament from eight .50 / six .60 caliber machine guns to six .50 / four .60 caliber machine guns and reduce the maximum combat range to 705 miles.[56]

Republic's engineers, when first considering a jet fighter design in the summer of 1944, had originally contemplated simply placing the engine in a modified P-47 fuselage. This quickly proved to be unworkable, as the P-47 fuselage was far too large to make this practical.[57] In the end, the XP-84 design was almost entirely new. The axial flow TG-180 engine (eventually manufactured by Allison as the J35) was more slender than the centrifugal flow engines used in the P-59 and the P-80. This, coupled with the straight through airflow from the nose intake, allowed the XP-84 to have a far more slender fuselage than the P-80. Despite having essentially the same thrust available as the P-80, the XP-84 was expected to have superior performance. This fact, at least for some Air Force officers, justified the procurement of a fighter that was in many ways very similar to the P-80.[58]

The XP-84 was a fairly simple, aerodynamically clean design. The essentially circular fuselage began with an air intake, and gradually broadened until just past the forward-set bubble

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canopy. The fuselage then began to narrow, becoming quite slender at the tail. The square-tipped wings were mid-mounted on the fuselage. The very wide tricycle landing gear had the main gear legs mounted halfway out on the wings and the nose wheel at the very tip of the fuselage.

ATSC contracted with Republic for three XP-84s, plus a static test model, mock-ups and engineering data on 11 November 1944. The total cost of this was to be $2,518,397 plus a four percent fixed fee. The third of the XP-84s was to incorporate changes mandated by the 689 Engineering inspection, plus carry .60 caliber machine guns instead of the earlier machine's .50 caliber.[59]

In early November 1944, even before mock-ups of the XP-84 underwent wind tunnel tests at NACA facilities, the Air Force demonstrated its confidence in the project by suggesting that Republic cancel 100 of its P-47s and substitute 100 P-84s instead.[60] This arrangement was formalized later in December and early January of the following year.[61] This action was contrary to the usual practice of testing the prototypes thoroughly before any production contract was issued. For example, the Air Force had not even considered ordering YP-80's until after the XP-80 had flown, and did not even discuss quantity orders for the P-80 until the XP-80 had undergone considerable flight testing. Now the Air Force authorized quantity production of a brand new type of airplane even before the mock-up had been completed or construction of the initial prototype had commenced! "Jet fever" had hit the Air Force hard.

During the remainder of the war, the XP-84 project pushed along rapidly, marred by problems uncovered by NACA during various tests. The aluminum skin on the stabilizer had bulged noticeably during tests, leading to concerns that the tail structure might be unsound.

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Despite arguments from Republic's engineers that similar designs on the P-47 had not proved unsafe, the tail had to be modified for increased strength.[62] Still more tail strengthening was in order when NACA wind tunnel tests showed longitudinal instability.

Modifications such as these caused considerable concern for Republic's engineers and the Air Force. As the war in the Pacific ended, Republic and the Air Force were grappling with the problems of the newest fighter in the Air Force arsenal.

> Problems relating to weight and balance had received considerable discussion at conference at contractor's plant 31 July. Gross weight was increasing and would continue to increase unless an "aggressive attempt was made to reduce the weight in every conceivable manner." Conferees agreed upon a revised version, new version to have design gross weight of 13,400 lbs. and maximum combat radius of 790 miles - estimated - at 37,000 feet.... Contractor was to keep within specific weight limitations (13,400-13,500 lbs.) and to expedite delivery of service test airplane.[63]

Republic continued to forge ahead with the project, and the end of the war had little or no effect on the pace of the program or the Air Force's interest in it.

The final entry in the Air Force's jet fighter roster during the war was the XP-86. The XP-86 came to the Air Force in a rather roundabout manner. In 1944, North American Aviation was looking for additional customers, and looked to the United States Navy. They performed tests with their superb P-51 Mustang on aircraft carriers, in an attempt to interest the Navy. They also discussed a number of proposals to modify the Mustang in various radical ways for service aboard carriers.[64]

The Navy was not interested in new piston-engined fighters for its carriers, however. They already had the solid and dependable Grumman F6F Hellcat, the elegant and deadly Chance-Vought F4U Corsair (called "Whistling Death" by the Japanese), with the speedy and nimble

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Grumman F8F Bearcat coming into service soon. What the Navy was interested in was the new jet engine technology. They asked North American to produce a jet fighter for consideration for carrier service. North American responded with the XFJ-1, later named the Fury.[65]

The Fury was in some regards similar to the XP-84. Designed to use the same TG-180 axial flow engine, it also used an air intake in the nose and a straight through airflow. Much of the XFJ-1 design was borrowed from the P-51, including straight laminar flow wings and a similar tail surface.[66] While the fuselage of the XP-84 was slender, indeed almost thin near the tail, the XFJ-1 had a much thicker fuselage, as well as much sturdier landing gear. Navy planes must be able to land on aircraft carriers, and a carrier landing is essentially a controlled crash, rather than a gentle touchdown. As a result, Navy aircraft must have more strength than their Air Force counterparts, and are often heavier and more robustly constructed.

Aside from the new jet engine technology, there was nothing special or radical about the XFJ-1. It's performance was expected to be roughly similar to other jets in production or development, such as the P-80, as well as Navy aircraft such as the McDonnell XFD-1 Phantom and the Vought XF6U-1 Cutlass. Although the Navy was interested in the XFJ-1, and would eventually order a number of Fury variants, the orders would be small, and North American looked to expand the market for its new product. With that in mind, they began to consider the Air Force fighter requirements that had prompted the creation of the XP-84.

On 18 May 1945, the Air Force asked North American to modify the XFJ-1 so that it could match the Air Force performance requirements. The result was given the designation XP-86, and three prototypes (45-59597, 45-59598, 45-59599) were ordered.[67] To create the XP-86, North American removed many of the features necessary to strengthen the aircraft for carrier

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landings, as well as elements needed to aid in the design's low speed flight characteristics (of more importance to a plane taking off from or landing on a carrier than to one using a long runway.) The result was a design that was in many ways quite similar to the XP-84. The fuselage of the XP-86 was more slender than the XFJ-1, although lacking the rearward taper of the XP-84. The straight, laminar flow wings were mounted well forward, at the bottom of the fuselage. A partial mock-up (fuselage plus the left side wing and elevator) was constructed to demonstrate the concept to the Air Force. This mock-up was inspected by the Air Force on 20 June 1945, and approved.[68]

The original XP-86 concept envisioned dive brakes on the upper and lower wing surfaces, and wingtip tanks. Dive brakes were a feature used on many aircraft, most notably dive bombers but also fighters and occasionally even conventional bombers. They vary in location and appearance, but all have one function - when engaged, they add drag and so help slow the airplane down. A number of aircraft used the so-called 'bench' dive brakes, including the German Ju 87 *Stuka* dive bomber and the Ju 88 medium bomber, and the Japanese Aichi Val dive bomber. These devices normally were positioned parallel to the underside of the wings, but when deployed rose perpendicular. They were composed of a series of slats on a frame, giving them a resemblance to a park bench seat, hence the name.

American dive bombers, such as the Douglass SDB Dauntless and Curtiss SB2C Helldiver, used circular perforated split flaps. These flaps were used for normal purposes, but could also be extended both above and below the wing to create additional drag. Other planes, such as the North American A-36 Apache and the Gloster Meteor, used a recessed, perforated panel on both the upper and lower surface of the wings, which could be raised perpendicular to

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the wing to generate drag. The XP-86 had this type of dive brake.

With dive bombers, the purpose of the dive brakes was to slow the plane down, both to allow accurate aiming of the bomb, and to prevent excessive g forces on the pullout after the dive. With exceptionally fast airplanes, such as the Meteor and the XP-86, the dive (or, as they would increasingly come to be known as, air or speed) brakes were intended to help prevent compressibility.

Although the Air Force had approved of prototypes of the XP-86, this was hardly a ringing endorsement of the project. Air Force officials noted that the XP-86 offered no significant advantages over the XP-84. Since the Air Force was already committed to the XP-84 project, they certainly would not be interested in another plane which offered no substantial improvement over it. Duplication of effort, especially in military affairs, usually leads to *less* efficiency, not more. It is almost always better for an organization to have one or two main pieces of equipment for a given task, even if their performance is not the best, rather than dozens of different ones, even if some of them are excellent performers. The increased performance is not adequate compensation for the massive increase in supply and maintenance problems. So the Air Force would be understandably reluctant to add a third jet fighter to their roster, producing even more supply, maintenance and training hassles, if that aircraft offered no significant performance improvement over the first two.[69]

Some means needed to be found to enhance the XP-86's performance if it was to be deemed worthy of production. Increasing the speed of the XP-86 was perhaps the best way to ensure the Air Force's interest. The fighter requirements had specified a level speed of 600 mph. Although Republic confidently predicted that the XP-84 could attain this speed, it would prove

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able to do so only under the very tightly controlled circumstances of high speed trials. North American wanted to provide a machine that could obtain this speed consistently, under normal operating conditions. The difficulty with this ambition was that the XP-84 design represented the peak performance that could be obtained with the power of the TG-180 engine and a conventional design.

The main problem with attempting to make a design like the XP-84 or XP-86 reach speeds of 600 mph was the design of the plane itself, or more specifically, the wings. At speeds over 500 mph, the combination of the higher drag and compressibility limited the speed at which the aircraft could safely fly. American aircraft designers had theorized about the advantages of angling, or sweeping, the wings back to reduce the effects of drag at high speeds. This feature had never been applied to an aircraft with sufficient performance to test the theory, however. Adding to the reluctance of the Air Force to consider such designs was the fact that although a swept wing would improve high speed performance, it adversely affected low speed flight characteristics. As a result, this feature had never been tested on high speed American aircraft.

By sweeping the wings back, the airflow pattern is changed, drag is reduced and the turbulence associated with high-speed flight is partially deflected from the wing surface. This allows an airplane with swept wings to fly faster than a similar airplane with straight wings, using the same power plant. An example of this is the Me 262 and Gloster Meteor. They had almost the same amount of thrust available from their engines, but the Me 262 with its mildly swept wings was at least 60 mph faster than the Meteor with its straight wings.

The same characteristic, however, creates instability and provides less lift at low speeds. A plane with swept wings would be very difficult to take off and land, for example, unless some

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means were found to increase the lift and dampen the instability.

Even as work progressed on the straight-wing XP-86 and North American engineers began to consider alterations to the design to improve its speed, circumstances would provide them the means to do so successfully. The end of the war in Europe had provided the American military with access not only to intact samples of various German aircraft, including their latest jet fighters, but also to the research, test results and engineering studies that had helped to produce them. The planes were shipped back to the United States, along with the research material.

This was the result of Operation Paper Clip, an American effort to obtain as much German scientific, technical and engineering information as possible at the end of the war. One of the prime areas of interest for this operation was an analysis of the German atomic research, but other areas of interest were such things as jet and rocket propulsion and various types of missiles and rockets. A large number of German aircraft were captured and shipped back to the United States for evaluation. The project also interrogated a large number of German scientists, technicians and engineers, allowing many of them to emigrate to America. Probably the best known of these emigres was Wernher von Braun, the father of the German guided missile program, and a major influence on America's subsequent missile program and space race.

North American was particularly interested in studying the Me 262, which had achieved remarkable performance, attributed in part to the fact that it's wings had a mild (15 degrees) sweep-back. The North American team wanted to find out how they had managed to overcome the low-speed handling problems inherent with such a design. Larry Green, head of North American's Design Aerodynamics, attended night school to study German, so that he could work directly with captured test results and engineering studies. The Air Force provided a captured Me

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262 to the company as well, for direct study.[70]

After study, it was discovered that the Me 262 dealt with the problems of low speed handling by the use of automatic leading edge slats. These slats normally were recessed into the wing, forming the leading edge, but at low speeds they automatically deployed, projecting forward and angling downward, to alter the shape of the wing. This altered wing shape increased the lift available from the wing, and largely offset the handling problems associated with a swept wing at low speeds. It was also discovered that the Germans had been working on a considerably modified version of the Me 262. This improved version would have featured more powerful engines, buried in the fuselage at the wing roots, rather than hanging under the wings in nacelles as in the original, and would increase the angle of the wing sweepback from roughly 15 to about 30 degrees. Much preliminary work had been done for this version of the Me 262, including wind tunnel testing of the airframe.[71]

It was this work that provided the inspiration for the alteration of the XP-86. On 14 August 1945, North American received a government grant to fund development of a swept wing for the XP-86.[72] By using a moderately swept (approximately 35 degrees) wing, and coupling that with automatic leading edge slats, North American transformed an ordinary and somewhat sedate jet fighter into a true thoroughbred. The revised XP-86 ultimately became the best of the first generation of American jet fighters, and found fame in the skies over a then-unfamiliar Asian peninsula only a few years later.

Many secondary sources written about the F-86 seem to be somehow embarrassed to admit that it was only after obtaining access to German information and aircraft that the XP-86 was transformed into a first class aircraft. Robert F. Dorr, in his excellent book ***F-86 Sabre:***

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History of the Sabre and FJ Fury, says that "it wasn't as if the Germans had thought up this innovation all by themselves. American designers had long ago proposed swept wings for some aircraft but had run up against a total lack of interest at the newly completed Pentagon building in the days prior to the Axis surrender."[73] What Dorr neglects to mention is that none of the designs employing swept wings had high enough performance to justify the time and effort any attempt to solve the stability problems inherent with swept wings would have cost.

It is true that a number of American fighter designs had incorporated swept wings. One of these, the Bell XP-52/XP-59 had not progressed beyond the mockup stage before being canceled. Two others, the Curtiss XP-55 Ascender and the Northrop XP-56 Black Bullet, had been designed to meet specifications for "unorthodox aircraft". Neither had performance that justified the problems caused by their unusual designs, and did not precede past prototype stage. The final swept wing design was the previously discussed Northrop XP-79B flying wing. American designers were familiar with the concept of the swept wing, but had never used it on an aircraft with high enough speed potential to make it worthwhile to attempt to solve the attendant problems that went with it.

There was no reason for the Air Force to pursue these designs, although one, the Curtiss XP-55 Ascender, did receive extensive flight testing, and revealed a number of very nasty performance problems resulting from the swept wing. During stall tests of the first prototype, the plane flipped onto its back, refused to return to an upright orientation, and then lost power. The pilot was forced to abandon the aircraft when efforts to restart the engine failed. Even after modifications to correct this problem, the XP-55 had extremely unpleasant, even dangerous low-speed handling characteristics.

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The puzzling thing about North American's difficulties with the concept of a swept wing and the low speed handling problems was that the solution adopted, leading edge slats, had been a part of combat aircraft design for almost a decade. Professor Willi Messerschmitt, the head of Messerschmitt AG, had been using this feature in his designs since the mid 1930's. Two of his very well known early designs, the Bf 109 and Bf 110, which were both in German service before the outbreak of hostilities, used the feature, as did many of his later designs, such as the Me 163 and Me 262. A further outstanding example of using the slats to improve lift was the Fiesler Fi 56 *Storch* (Stork), a German STOL (Short Take Off and Landing) liaison aircraft capable of amazingly short take off runs. So the concept of using leading edge slats to improve low speed handling had been around for many years, and was known to the Allies through captured equipment. Why, then, was it so difficult to make the conceptual leap to combining a swept wing with leading edge slats?

It is likely that this was a case of institutional preconceptions and tunnel vision. This sort of thinking can be seen in the U.S. Air Force's decision to equip almost all of its fighters with nothing larger than .50 caliber machine guns,despite the fact that all other air forces were making extensive use of 20 mm (and larger) cannon as aerial weapons. This emphasis on machine gun armament would prove troublesome to American pilots over Korea, when it often could take an F-86's entire ammunition load to down a single MiG-15.

The Browning .50 caliber machine gun was an excellent, sturdy and reliable weapon that served a wide variety of functions in the American military. It was employed as secondary armament on armored vehicles, as an infantry support weapon, as an anti-aircraft weapon, and as the primary armament on both bombers and fighters. The very excellence of the weapon may well

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have played a role in the Air Force's reluctance to seek a replacement (although some serious attempts were made to develop a larger version, the .60 caliber machine gun).

The .50 caliber was possibly the best overall heavy machine gun employed by any of the combatants during the war, with a large bullet, high velocity, respectable range and adequate rate of fire. As aircraft armament, against relatively lightly-constructed opponents, such as German fighter aircraft or virtually any Japanese aircraft, the .50 caliber was ideal. Six .50 caliber guns became the standard American fighter armament, although the P-47 had eight.

Before the war, the British had calculated that they needed heavy firepower for their fighters to successfully engage enemy bombers. Thus, the early versions of the Spitfire and Hurricane fighters were armed with eight .303 caliber machine guns. During the Battle of Britain, it was discovered that this armament was inadequate to ensure the destruction of German bombers. German bombers would frequently return to their bases in France with dozens or even hundreds of bullet holes in them, but with little or no serious structural damage. As a result of this, subsequent models of both planes were armed with 20 mm cannon, as were all new British fighters.

Likewise, German fighter aircraft were increasingly heavily armed to combat the giant Allied bombers. The Fw 190 single engined fighter could carry as many as six 20 mm cannon, and the Me 262 had four 30 mm cannon. Cannon had a considerably lower rate of fire and significantly less ammunition capacity than machine guns. However, cannon shells could be made to explode on impact, unlike the solid machine gun bullets, giving them enormously greater destructive potential. German tests with 30 mm cannon concluded that just one shell hitting a fighter plane would destroy it, and only two or three hits would be needed to bring down a four

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engined bomber.

Probably a major influence on the development of American fighter armament was the fact that the American air forces (both Army and Navy) were rarely faced with the need to combat large, powerful and sturdy combat aircraft, unlike the British, Germans, or Japanese. There was therefore no institutional need to seek more powerful armament for their aircraft. American pilots would pay a price for this attitude over the skies of Korea, when they attempted to combat the tough MiG-15.

Another example of this sort of institutional mind set can be seen in Germany, where German designers proved reluctant to use 'tricycle' landing gear, with a nose wheel, preferring instead the older 'tail dragger' configuration. This attitude persisted despite the demonstrated efficiency and improved visibility of the tricycle arrangement. Only late in the war did a handful of German aircraft begin to use this arrangement. Most of those that did so were jets, which had to use tricycle gear due to the nature of their powerplant. American designers, in contrast, used tricycle landing gear almost interchangeably with the tail dragging configuration. Many American planes, including the P-38, P-39, P-61, B-24, B-25, B-26, A-20, and A-26 and used this arrangement.

The United States Air Force, although coming late to the idea of jet propulsion, proved to be an enthusiastic convert once the potential of this new power source had been demonstrated. Indeed, it might be accurate to characterize the Air Force as going a bit "jet crazy" late in the war. Although the potential threat from the Me 262 and other German jets was quite significant, the American enthusiasm for new jet aircraft cannot be explained solely as a response to external threats. Other factors seem to have been at work, as well.

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Although it may seem frivolous, it is difficult to escape the idea that jet fighters were, at least in part, a wonderful new "toy" for the Air Force to play with. Certainly the Air Force's interest in and desire for these new airplanes far exceeded any logical need for them. And one has only to observe the American fascination with technology, from consumer electronics to power tools to vehicles of all types, to see that desires for new technology need not be rational to be real.

The P-80 is perhaps the best example of this fascination. The performance of the airplane was certainly impressive (although some of the pride in this performance would fade a bit when the P-80 was tested competitively with captured German jets) but that is insufficient to justify the virtual frenzy of the Air Force to acquire the aircraft. Likewise, the threat of the German jets was certainly real, but the Allies had excellent technical intelligence about them, and were in fact coping quite well with the challenge they presented. Especially by the spring of 1945, it was obvious that German jets would not be a threat for much longer, if only because Allied ground troops were overruning their bases. And if the German jets were the basis for this intense interest, then why was the P-80 program continued at such a fever pitch even after Germany had surrendered? After all, no one had taken Japanese aviation seriously for more than a year before, ever since the massacre of the Great Marianas Turkey Shoot. American B-29 bombers roamed virtually unmolested over Japan. So what was all the excitement about?

In the documents associated with the wartime production of the P-80, over and over again one finds Air Force officers literally frantic because they didn't have any P-80s. The P-80 was to them a sort of "wonder weapon" that would help the Air Force win the war. They seem to have overlooked the fact that the armed forces (including the Air Force) were winning the war rather

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handily even without the P-80. There seems to have been a sort of service-oriented "tunnel vision" infecting many Air Force officers that kept them from paying much attention to developments outside their narrow specialization. As late as the end of January 1945, Air Force Lieutenant General Miles said at a staff meeting in Washington "that the situation in ETO in regard to the growing use of German jet fighters and the threat which would soon be offered in this connection made the early operational use of the P-80 the only effective counter measure....'I want now to produce the P-80 in quantity soon and am ready to accept substantial losses in other aircraft production if necessary.'"[74]

General Miles appeared to be unaware that Allied armies were poised on the borders of Germany, soon to be moving into the heartland of Hitler's Thousand Year Reich, and that the once-vaunted *Luftwaffe* had been reduced to a shell. The last major *Luftwaffe* effort, Operation *Bodenplatte* (Baseplate) had taken place on New Year's Day, 1945. This surprise low level attack on forward Allied airbases cost the Allies several hundred airplanes, mostly fighters, but few pilots. The Germans, in contrast, had lost over 500 planes, and virtually all of the men flying them. Since then, large-scale *Luftwaffe* operations had been non-existent.

The jet operations that General Miles was so fearful of were never more than a minor nuisance to the Allied air armadas. The single strongest German jet attack occurred on 10 April 1945, when Me 262's made fifty-five sorties against Allied bombers. That is, fifty-five Me 262's from a variety of different combat units took off at various times during the day to engage the bombers. Of those fifty-five Me 262's, forty-eight made contact with the enemy, claiming nine kills and three probable kills. American records indicate the loss of ten bombers that day. For this result, the Germans lost twenty-seven of the Me 262's, with five pilots killed and fourteen more

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missing.[75] And this was the most successful day of German jet operations. At a time when the Americans alone could routinely send 1,000 bombers escorted by 600 fighters on bombing missions, these losses hardly qualify as crippling. Most German jet actions were far smaller, with sorties by two or four planes the norm.

The effect of the Me 262 seems to have been psychological, rather than physical. There was the very real and understandable fear of the unknown coupled with the formidable observed performance of the Me 262. Quite likely equally important in American Air Force officer's minds was a case of what might be called "jet envy." This condition has persisted throughout the Cold War, with each newly revealed Communist aircraft prompting anguished cries from the Pentagon for a new, more complex, and more expensive aircraft for the American Air Force to match it.

Indicative of just how seriously the threat of the Me 262 featured in prompting Air Force orders for the P-80, was the fact that when Germany finally surrendered in May 1945, the Air Force did cancel some P-80's from their contracts. The entire contract for the P-80N, produced by North American, was canceled within a few days of the end of the fighting in Europe, and 452 planes were dropped from the order with Lockheed. This sounds very impressive - it is a cancellation of almost 3,000 machines - until it is remembered that this still left Lockheed committed to produce over 6,000 jets over the next year and a half.[76]

The surrender of Japan did lead to further cancellations of P-80's. By the summer of 1945, Lockheed was committed to producing almost 7,000 P-80's. Between the middle of August and the end of September of 1945, the Air Force canceled approximately 2,600 P-80's.[77] This still left over 4,300 on order from Lockheed. Eventually the Air Force (aided by Congress's drastic spending cuts) did cancel sufficient P-80's to bring the number on order down to just under

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one thousand.

It is worth noting that the Air Force canceled *all* of its orders for piston engined fighters during this same period. When the fighting ended, the Air Force very quickly divested itself of all the piston engined fighters it had been using, save for the workhorse P-47, the superb P-51 Mustang, and its unusual stepchild, the F-82 Twin Mustang, a long-ranged all-weather interceptor. These planes served in active units only until they could be replaced by jets, when they were relegated to Reserve and Air National Guard units.

It should be pointed out that this tremendous eagerness to get rid of all piston-engined aircraft was not universal in the American military. A noted contrast to the Air Force's attitude towards piston engined fighters can be seen in the U.S. Navy. The Navy's primary post-war fighter for a number of years was the superb Vought F4U Corsair, which remained in production until the mid 1950's. Although gradually replaced by jets, the Corsair continued to serve in active and reserve units for many years in the Navy and Marine Corps. The Navy and Marine Corps also continued to use a variety of other piston-eneinged combat aircraft, including the F7F Tigercat, the F8F Bearcat, and the AD Skyraider, all of which remained in production after the war was over.

This desire for large numbers of the P-80 seems to have existed in the Air Force independent of any immediate actual combat need for the aircraft. The P-80 project was initiated before the Air Force was aware of the existence of the Me 262, and much of its development occurred largely isolated from external developments. Only after the XP-80 had actually flown and early reports of German jets began to circulate did the Air Force seize on the German jet threat as a rationale for massive production of the P-80. To be fair, the Me 262 did represent a

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very serious potential threat to Allied bombers, and the Allies were generally unaware of the various technical problems that largely crippled its development. Perhaps the Me 262 was the initial spur to Air Force interest in the P-80, but that interest seems to have acquired a life of its own, continuing well after the threat was eliminated.

Following the German surrender, American attention turned to the Pacific theater. Deprived of a chance to use their own jet to thwart the German machines, the Air Force felt it imperative to get the P-80 into combat in the Pacific. "AC/AS, OC&R (Wash.), stated the belief that it was of vital importance that the jet fighter be put into combat during the war; one reason for this was that it would contribute more to the future development of military aircraft than would several years of peacetime operation."[78] The reasoning behind this had little to do with the realities of air combat, and much to do with the nature of defense politics and interservice rivalry. One possible explanation for the urgent efforts of the Pentagon's Air Force generals to deploy the P-80 into combat before the end of the war may well have been a desire to position themselves for the anticipated post-war budget cutbacks. Operational deployment of the P-80 would give them the ability to claim the Shooting Star as a "combat-proven" weapon, one more worthy of the allocation of limited budget dollars than an untested prototype. Of course, this tactic could well have blown up in their faces had the P-80 been deployed before the major problems with the airplane had been worked out.

Another component of this attitude of the Air Force seemed to have been that they had this marvelous new toy, and wanted more than anything to play with it, but they were afraid the game would be over before they would have a chance try it out. The idea that operating a handful of jets in combat would "contribute more to the future development of military aircraft" was pure

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fantasy. There were even some clear-headed Air Force officers who recognized the absurdity of this line of thinking.

> AC-AS, OC&R (Wash.), discussed the plan for early use of six P-80A's in the Pacific and stated that that office had consistently resisted all efforts to commit the P-80 to combat [implying numerous attempts to do so] before it could be employed in sufficient numbers to be decisive. The desperate efforts of the Germans to save the prestige [interesting word choice!] and existence of the Luftwaffe by premature commitment of their jet and rocket type aircraft proved the wisdom of this policy. There was nothing to indicate that the Japanese had any fighter or would have one within the next six or eight months which could match the late models of the P-51 and P-47 in performance, and, if the P-80's were parceled out in small increments, the AAF would be unable to meet a real need for the airplanes if such a need arose in the future. [thinking of the Russians already, perhaps?] The capabilities of the P-80 had been widely publicized, but it was acknowledged by all concerned that the airplane still had many "bugs" to be worked out. It was concluded that the doubtful advantages to be gained by commitment of a few P-80's were far outweighed by the possibility of a serious setback of the entire jet program resulting from initial failure, by the fact that no requirement had yet been expressed in the Pacific for a fighter capable of superior speeds, and by the undesirability of committing an untrained unit to combat with an entirely new and untested weapon.[79]

The Japanese did possess a large number of combat aircraft in late 1945, but virtually all of them were being readied for use as part of the "Special Attack Squadrons," more popularly known as the *Kamikaze*s. Except for a handful of veteran ace pilots, by 1945 both the Japanese Army Air Force and the Japanese Naval Air Force were completely incapable of resisting the American aerial juggernaut.

Many of the *kamikazes* were obsolete or training aircraft, flown by pilots so inexperienced that some of them had not even been trained to land the plane. More to the point, the *kamikazes* focused their attention on the ships of the United States Navy, specifically when they were

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stationed off the coast of an island during an invasion. Under the circumstances, there was little the Air Force could have done to assist the Navy, even assuming such assistance was desired or requested. Finally, although Japan was, as was mentioned in a previous chapter, working on developing jet aircraft, none were even close to being operational, and the most likely to have seen action, the *Kika*, was both unarmed and slower than American piston-engined aircraft.

Significantly, a letter written on 23 July 1945, by Colonel H. A. Boushey, Jr., the commanding officer of the 412th FG outlining proposed tactical uses of the P-80 never even mentioned the kamikazes. The letter stressed that the P-80 would be ideal to "escort proposed jet-propelled bombers," to "combat enemy high-speed jet or rocket propelled aircraft," as well as "interception, partial escort, and target area support."[80] The first two categories were obviously unnecessary, as neither jet bombers nor enemy jet fighters existed, and the third was being handled admirably by piston engined fighters. Boushey also made a case for the P-80 as a ground attack machine, "because it had the advantage of a high speed, low level approach for surprise and protection."[81] What Boushey neglected to mention is that "high speed, low level approaches" were not ideal for tactical ground attack missions, as they provided virtually no time to locate and identify the target and aim the ordnance, making it almost impossible to actually hit the target. Perhaps the basis for Boushey's enthusiasm for this mode of operation can be found in the justification he offered - "surprise and protection." He seemed more concerned with avoiding damage to his airplanes than in performing the mission successfully. His desire for safety while performing this mission is certainly understandable, however, as far more American fighter aircraft during the war were lost to ground fire than to enemy aircraft. While it is commendable that as the commanding officer of the Air Force's only jet fighter unit, he should be eager to get

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his unit into action, he does seem to be grasping at some fairly thin straws justifify combat deployment.

Colonel Boushey's emphasis on the safety of his aircraft over effectively performing tactical ground attack missions is in fact typical of the attitude of many U.S. Air Force officers. Although there were exceptions, many Air Force officers considered any mission (including tactical ground support) that detracted from their self-chosen goal of strategic bombardment (and the closely related goals of the protection and/or destruction of those bombers) a waste of time and resources. This was in sharp contrast to the aviators of the United States Marine Corps, who considered it essential to support their comrades on the ground. In both the Pacific campaign of the Second World War and the Korean War, Marine Corps fighter pilots repeatedly attacked and destroyed ground targets that the Air Force claimed were impossible to attack successfully.

Since the first part of Operation Downfall (the code name for the invasion of the Japanese home islands), Operation Olympic (the invasion of Kyushu) was scheduled for early October of 1945 and the 412th was not scheduled to deploy to the Pacific until December of 1945, it is doubtful whether the 412th FG would have had an opportunity to participate in any aerial combat when it first deployed to the Pacific. Although Japan still possessed a large quantity of airplanes prior to surrender, virtually all of these were intended for use as *kamikazes* during the invasion of Kyushu, and it is likely that almost all of them would have been expended in combat by early December, 1945. Operation Coronet (the invasion of the main island, Honshu) was scheduled for the spring of 1946, but it is questionable whether Japan would have retained any significant quantity of combat aircraft by that point. If the atomic bombs had not been used, and the invasion of the Japanese home islands had proceeded as planned, the P-80 may well have deployed to the

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Pacific only to find a sky empty of enemy aircraft.

In addition to the diligent and occasionally convoluted attempts to justify the deployment of the P-80, another indication of the intensity of the Air Force interest in the plane was the manner in which its testing was conducted. Once flight testing began, especially once the XP-80As were available, nothing was allowed to slow the program down. Occasional technical and manufacturing problems created delays, and despite a number of spectacular and fatal in-flight accidents, the operational testing pace never slackened. The Air Force solidly resisted any attempts to ground the P-80s, at least as long as the war continued. It took the end of the war and the death of America's leading ace to force the grounding of the P-80's and the implementation of a slower and safer testing schedule.

Despite the Air Force's at times obsessive desire to get the P-80 into combat, there does seem to be a reason for the continued large orders of P-80s, well past any logical military need for them during the war. The Air Force had apparently decided that the jet was the combat aircraft of the future, and planned to completely re-equip its combat units with jets once the fighting was over. The jet fighter was the weapon of the future, and the piston-engined fighter was an obselete relic of the past. Of all the piston-engined fighters, only the F-82 continued in production, for only a few years, before being replaced by jet powered aircraft intended for the same mission.

In summary, the Air Force, following a sluggish and unresponsive start, had become an extremely passionate advocate of jet combat aircraft. During the war, they developed two production jet fighters, began quantity production of a third,with another five developed and/or tested. When hostilities ceased, the Air Force was well along the path to an all-jet fighter force. The jet fighter had indeed come of age.

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1. Republic Aviation was about to offer an issue of prefered stock, and had used this statement in their prospectus. The SEC sent a letter to the Air Force, attempting to verify it. The Air Force confirmed the the P-84 was indeed the most advanced plane in production at that time. Ernest W. Ramspeck, Assistant Director, Corporate Finance Division, Securities and Exchange Commission, Philiadelphia, to Air Material Command, 6 December 1946, November 27, Dorothy L. Miller ***Case History of the F-84 Airplane*** Historical Office, Executive Secretariat, Air Material Command, Wright Patterson Air Force Base, April, 1950.; located in the microfilm archives in the Library of the Office of Air Force History, Bolling Air Force Base, Washington, D.C.

2. Bill Gunston with Peter Gilchrist ***Jet Bombers: From the Messerschmitt Me 262 to the Stealth B-2*** London: Osprey, 1994, pp. 35-6.

3. The engines were Pratt & Whitney radials, each developing 3,500 hp. Ron Dick and Dan Patterson ***American Eagles: A History of the United States Air Force, Featuring the Collection of the U.S. Air Force Museum*** Charlottesville, VA: Howell Press, 1997, p. 265.

4. Jones, ***U.S. Fighters***, p. 222.

5. Lloyd S. Jones ***U.S. Naval Fighters: Navy/Marine Corps, 1922 to 1980s*** Fallbrook CA: Aero Publishers, Inc., 1977, pp. 84-8.

6. Doris A. Canham ***Development and Production of Fighter Aircraft for the United States Air Force*** Historical Office, Executive Secretariat, Air Material Command, Wright-Patterson Air Force Base, October 1949, pp. 85-6.

7. Jones, ***U. S. Fighters***, p. 179.

8. Canham, ***Fighter Aircraft***, p. 90.; Jones, ***U.S. Fighters***, p. 181.

9. Canham, ***Fighter Aircraft***, p. 91.

10. Jones, ***U.S. Fighters***, p. 179.

11. Ibid.

12. Canham, ***Fighter Aircraft***, p. 91.

13. Jones, ***U.S. Fighters***, pp. 179-80.

14. Ibid., p. 180.

15. Canham, ***Fighter Aircraft***, pp. 85-9; Jones, ***U.S. Fighters***, pp. 135-45.

16. Gunston and Gilchrist, ***Jet Bombers***, p. 36.

17. Jones, ***U.S. Fighters***, p. 199.

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18. Canham, ***Fighter Aircraft***, p. 108.

19. Ibid.

20. Jones, ***U.S. Fighters***, p. 199.

21. Canham, ***Fighter Aircraft***, p. 108.

22. Ibid.

23. Jones, ***U.S. Fighters***, p. 199.

24. Ibid.

25. Canham, ***Fighter Aircraft***, pp. 108-9.; Jones, ***U.S. Fighters***, p. 201.

26. ***Summary of Model XP-81 Flight Test Results: Feb. 7, 1945 to April 7, 1945*** Consolidated Vultee Aircraft Corporation, Vultee Field, California June 4, 1945. Microfilm Archives, Library of the Office of Air Force History, Bolling Air Force Base, Washington, D.C.

27. Canham, ***Fighter Aircraft***, p. 112.

28. Jones, ***U.S. Fighters***, p. 205.

29. Ibid.

30. ***XP-81 Flight Test Results***.

31. Canham, ***Fighter Aircraft***, p. 113.

32. Jones, ***U.S. Fighters***, p. 205.

33. Ibid.

34. Graphs, ***XP-81 Flight Test Results***.

35. Canham, ***Fighter Aircraft***, p. 113.

36. Ibid.

37. Ernest McDowell ***FR-1 Fireball Mini in Action*** Carrollton, Texas: Squadron/Signal Publications, 1995, p. 6.

38. Jones, ***U. S. Fighters***, p. 211.

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39. Larry Davis ***P-47 Thunderbolt in Action*** Carrollton, Texas: Squadron/Signal Publications, 1984, p. 6.

40. Jones, ***U.S. Fighters*** , p. 117.

41. Ibid., p. 211.

42. Ibid., p. 204.

43. Ibid., p. 211.

44. Ibid.

45. Canham, ***Fighter Aircraft***, p. 114.

46. Brig. Gen. Mervin Gross, Chief, Requirements Division, Assistant Chief of Air Staff, Operations, Commitments and Requirements, Washington, to Assistant Chief of Air Staff, Material and Service, Washington, 15 July, 1944, Miller, ***F-84 Case History***.

47. Col R.C. Wilson, Office of the Assistant Chief of Air Staff, Material and Service, Washington, to Engineering Division, 11 September, 1944, Miller, ***F-84 Case History.***

48. Republic Aviation Corporation, Farmingdale, Long Island, New York, to Chief of Engineering and Procurement, 2 November, 1944, Miller, ***F-84 Case History.***

49. Miller, ***F-84 Case History***, p. 1.

50. Republic Aviation Corporation, Farmingdale, Long Island, New York, to Chief of Engineering and Procurement, 2 November, 1944, Miller, ***F-84 Case History.***

51. Davis, ***P-47 Thunderbolt in Action***, pp. 14, 28.

52. Bert Kinzey ***F-84 Thunderjet in Scale*** Carrollton, Texas: Squadron/Signal Publications, 1999, p. 4.

53. Engineering Division to Assistant Chief of Air Staff, Material and Service, Washington, 2 November, 1944, Miller, ***F-84 Case History.***

54. Miller, ***F-84 Case History***, p. 1.

55. Engineering Division to Assistant Chief of Air Staff, Material and Service, Washington, 2 November, 1944, Miller, ***F-84 Case History.***

56. Miller, ***F-84 Case History***, p. 1.

57. Kinzey, ***F-84 Thunderjet***, p. 4.

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58. Ibid.

59. Letter of Contract W33-038-038 ac-6248, 11 November, 1944, Miller, ***F-84 Case History.***

60. Wire from Lt. Gen. W. K. Knudson, Director, Air Transport Service Command, to Maj. Gen. Oliver P. Echols, Headquarters, Army Air Forces, Washington, 10 November, 1944, Miller, ***F-84 Case History.***

61. Production Section, Procurement Division to Republic Aviation Corporation, 20 December, 1944; Excerpt from Letter of Contract W33-038 ac-7687, 4 January, 1945, Miller, ***F-84 Case History.***

62. Memorandum from Aeronautic Engineering, NACA, Langley Field, Virginia, to Chief of Research, NACA, Langley Field, Virginia, 24 May, 1945, Miller, ***F-84 Case History.***

63. Maj. Charles R. Able, Project Officer, Aircraft Project Section, Engineering Division, to Republic Aviation Corporation, 8 August, 1945, Miller, ***F-84 Case History.***

64. Robert F. Dorr ***F-86 Sabre: History of the Sabre and Sea Fury*** Osceola, Wisconsin: Motorbooks International Publishers, 1993, pp. 7-8.

65. Ibid., p. 8.

66. Chris Hughes and Walter Dranem ***North American F-86 SabreJet Day Fighters*** North Branch, Minnesota: Specialty Press Publishers, 1996, p. 8.

67. Dorr, ***F-86 Sabre***, p. 8.

68. Hughes and Dranem, ***SabreJet Day Fighters***, pp. 6, 10-1.

69. Dorr, ***F-86 Sabre***, p. 8.

70. Dorr, ***F-86 Sabre***, p. 8.

71. Boyne ***Me 262***, p. 119.; Shigeru Nohara and Masatsugu Shiwaku ***Messerschmitt Me 262A: Aero Detail 9*** Tokyo: Dai Nippon Kaiga Co., 1993, p. 80.

72. Hughes and Dranem, ***SabreJet***, p. 12.

73. Dorr, ***F-86 Sabre***, p. 8.

74. Routing and Record Sheet-1, from Brig. Gen. P. W. Timberlake, Deputy Chief Air Staff, Washington, to Assistant Chief of Air Staff, Material and Service, Washington, 30 January, 1945, ***P-80 Case History.***

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75. Ethell & Price, ***World War II Fighting Jets***, pp. 47-9.

76. As of 31 March, 1945, the P-80 production schedule was as follows:

For 1945	Lockheed	800 airplanes
	North American	61 airplanes
For 1946	Lockheed	6,631 airplanes
	North American	2,435 airplanes

Memorandum from Maj. Gen. O.P. Echols, Assistant Chief, Air Staff, Material and Supply, Washington, to Commanding General, Army Air Forces, Washington ***P-80 Case History***.

77. Termination Notice to Contract W33-038 ac-8388, 13 August, 1945,; Telegram Termination Notice to Contract W33-038 ac-8388, 5 September, 1945,; Telegram Termination Notice to Contract W33-038 ac-2527, 5 September, 1945, ***P-80 Case History***.

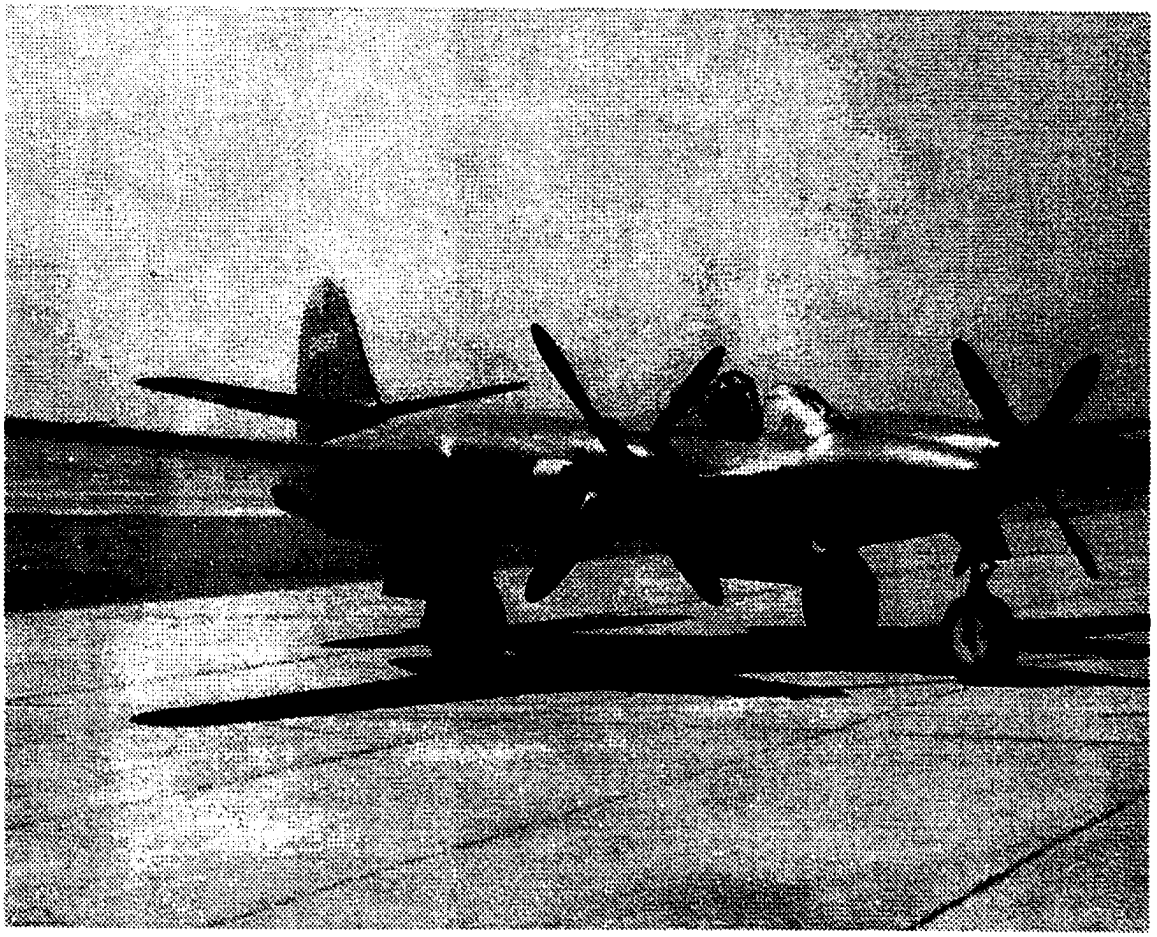
78. Record & Routing-1, from Lt. Gen. H. S. Vandenberg, Assistant Chief, Air Staff, Operations, Commitments and Requirements, Washington, to Maj. Gen. E. Powers, Assistant Chief, Air Staff, Material and Supply, Washington, 17 July, 1945, ***P-80 Case History.***

79. Routing and Record-2 from Maj Gen. D. Wilson, Assistant Chief, Air Staff, Operations, Commitments and Requirements, Washington, to Assistant Chief, Air Staff, Plans, Washington, 14 June, 1945, ***P-80 Case History.***

80. Col. H. A. Boushey, Jr., Commanding Officer, 412th Fighter Group, Santa Maria Army Air Field, Santa Maria, California, to Commanding General, Fourth Air Force, San Francisco, California, 23 July, 1945, ***P-80 Case History.***

81. Ibid.

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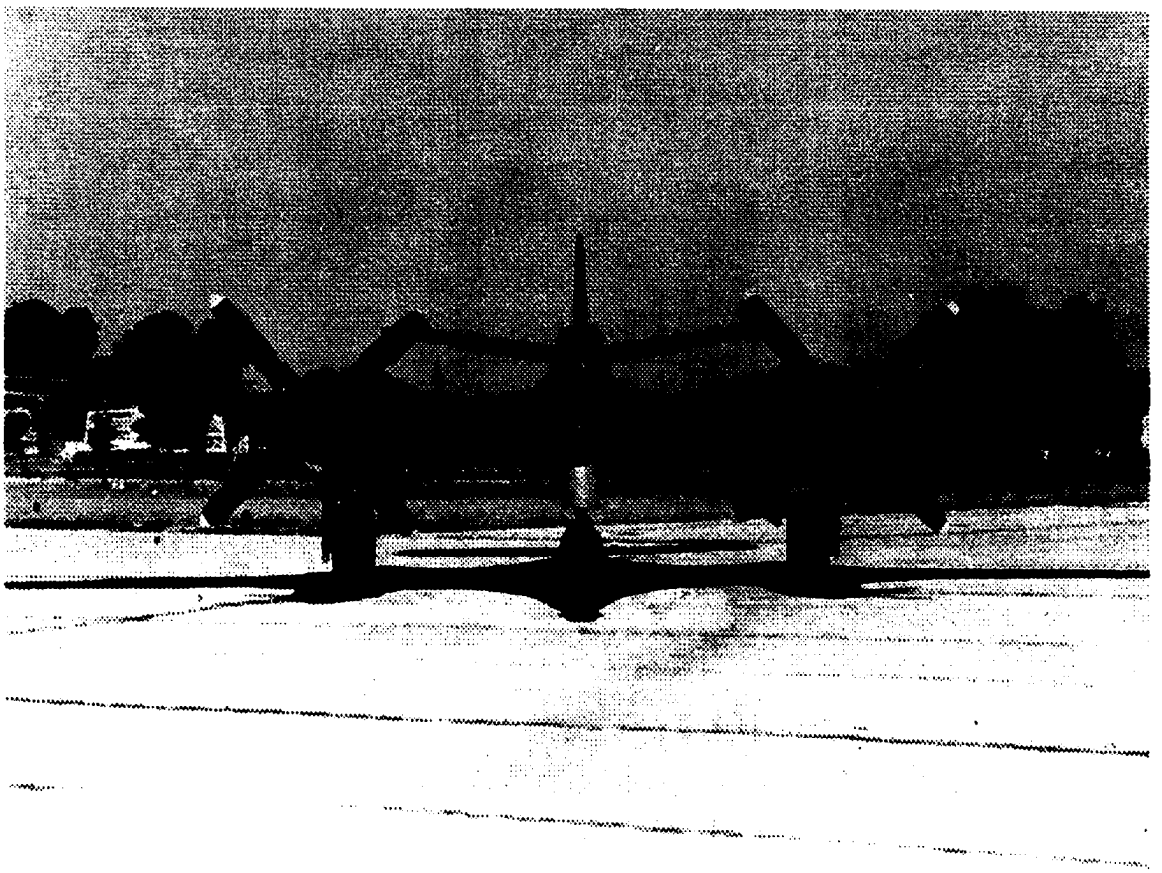
The McDonnell XP-67 Moonbat bomber interceptor. The low sleek design is obvious. Photo credited to Wright Field, dated 2 August 1944. (National Archives, Photographic Division, Box 2029, Number 29992)

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The XP-67 from the side. The exhaust outlet for the supercharger gasses is visible just ahead of the national insignia. Photo credited to Wright Field, dated 1 July 1944. (National Archives, Photographic Division, Box 2029, Number 29993)

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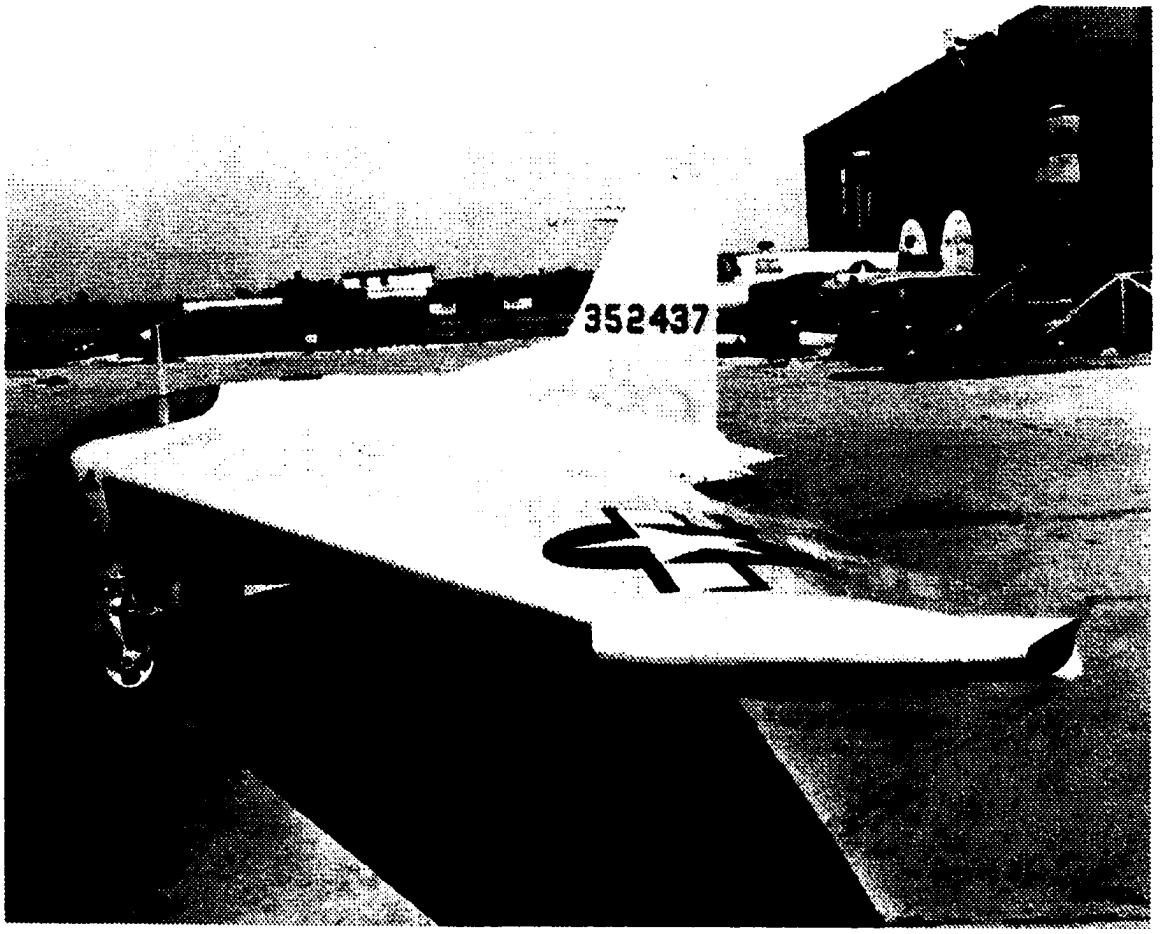
The XP-67 from the front. The low, smooth profile of the plane is especially obvious from this angle. Photo credited to Wright Field, dated 1 July 1944. (National Archives, Photographic Division, Box 2029, Number 29994)

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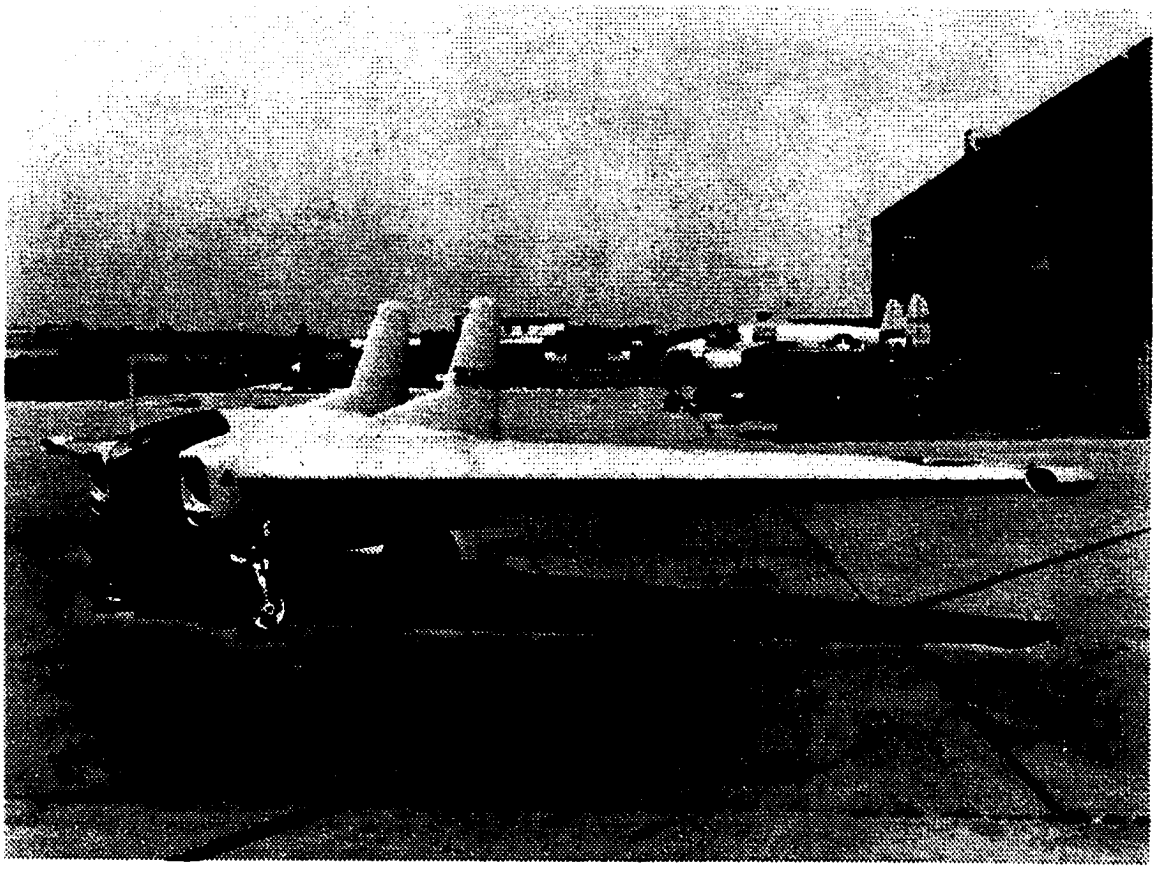
The XP-67 in flight. The exhaust nozzles for the jet boost are clearly visible on the rear of the engine nacelles. Photo credited to Wright Field, February 1945 issue of ***Air Force***, dated 5 February 1945. (National Archives, Photographic Division, Box 2029, Number 29995)

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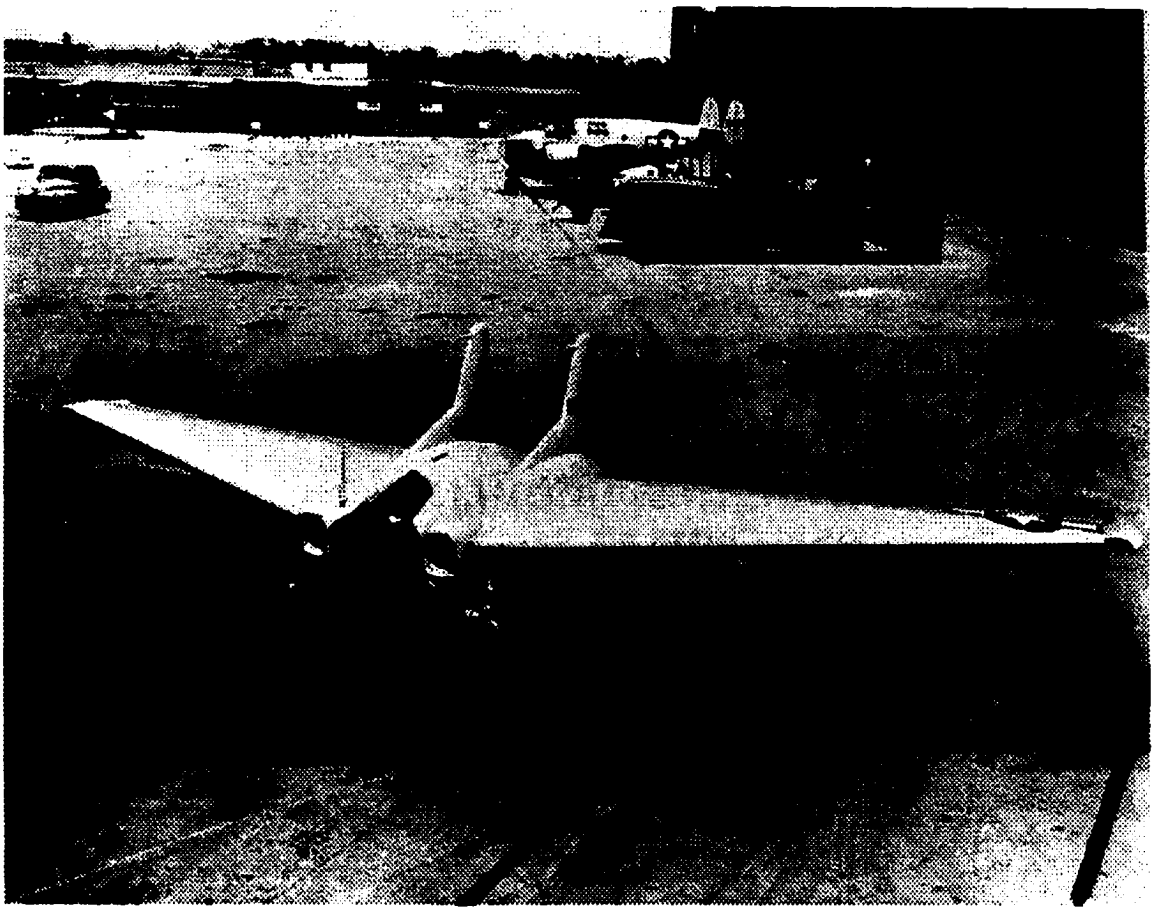
The Northrup XP-79B flying wing fighter. The wingtip bellows is prominent in this photo. Photo credited to Wright Field, dated 15 May 1946. (National Archives, Photographic Division, Box 2029, Number 30034)

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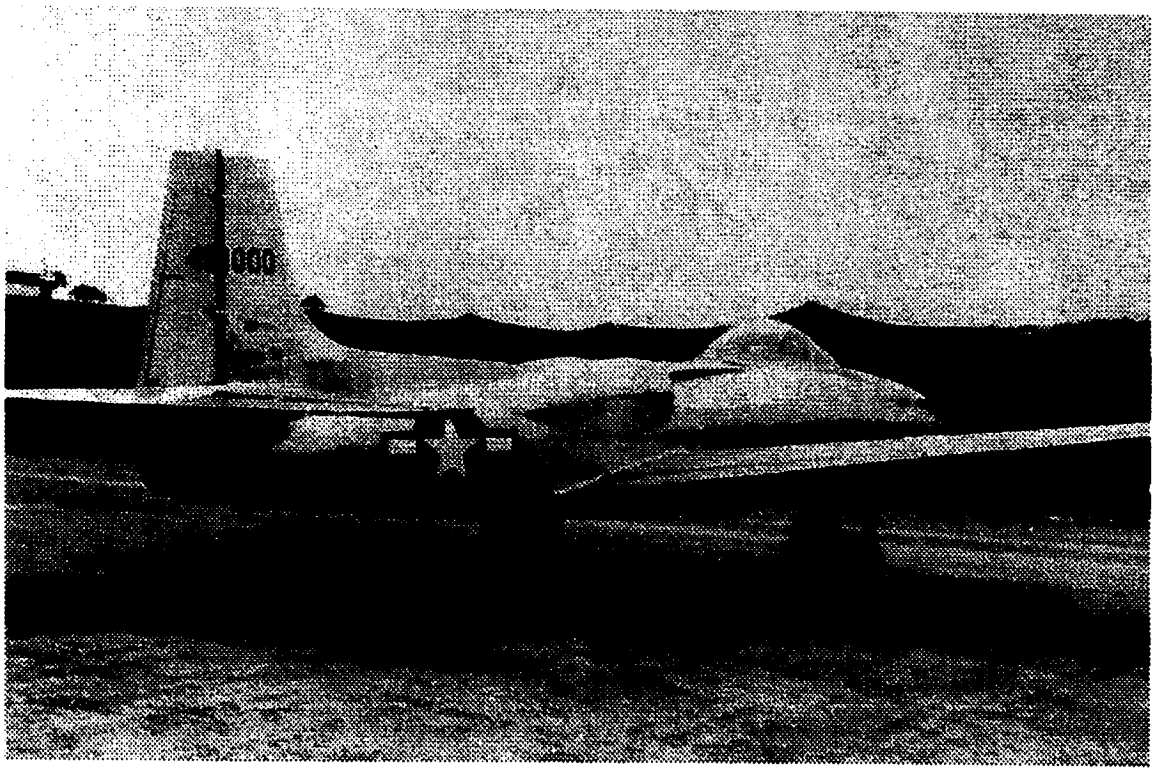
The XP-79B. The twin intakes for the jet engines can be seen, as can the prone-position pilot's compartment between them. Photo credited to Wright Field, dated, 19 June 1946. (National Archives, Photographic Division, Box 2029, Number 30035)

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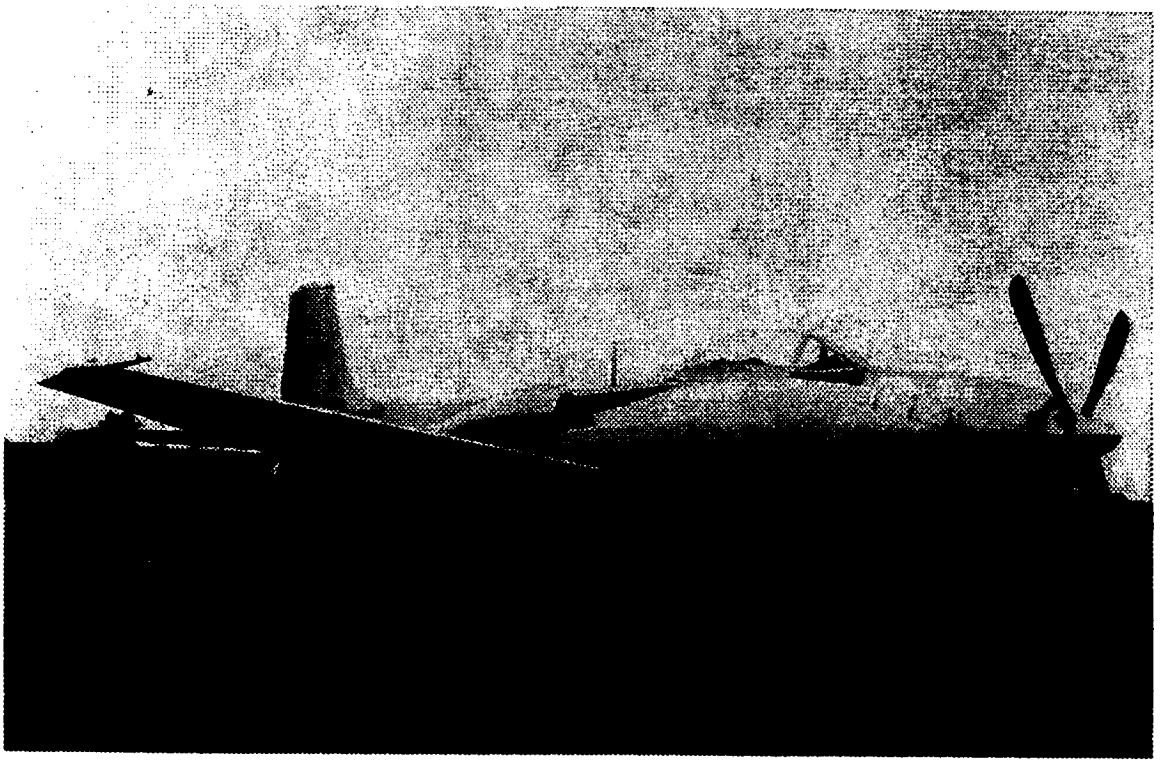
The XP-79B from above. The unusual nature of the aircraft, from the wide-track four point landing gear, to the wingtip bellows in place of conventional rudders, to the low prone cabin, can all be seen to advantage in this view. Photo credited to Wright Field, dated 15 May 1946. (National Archives, Photographic Division, Box 2029, Number 30036)

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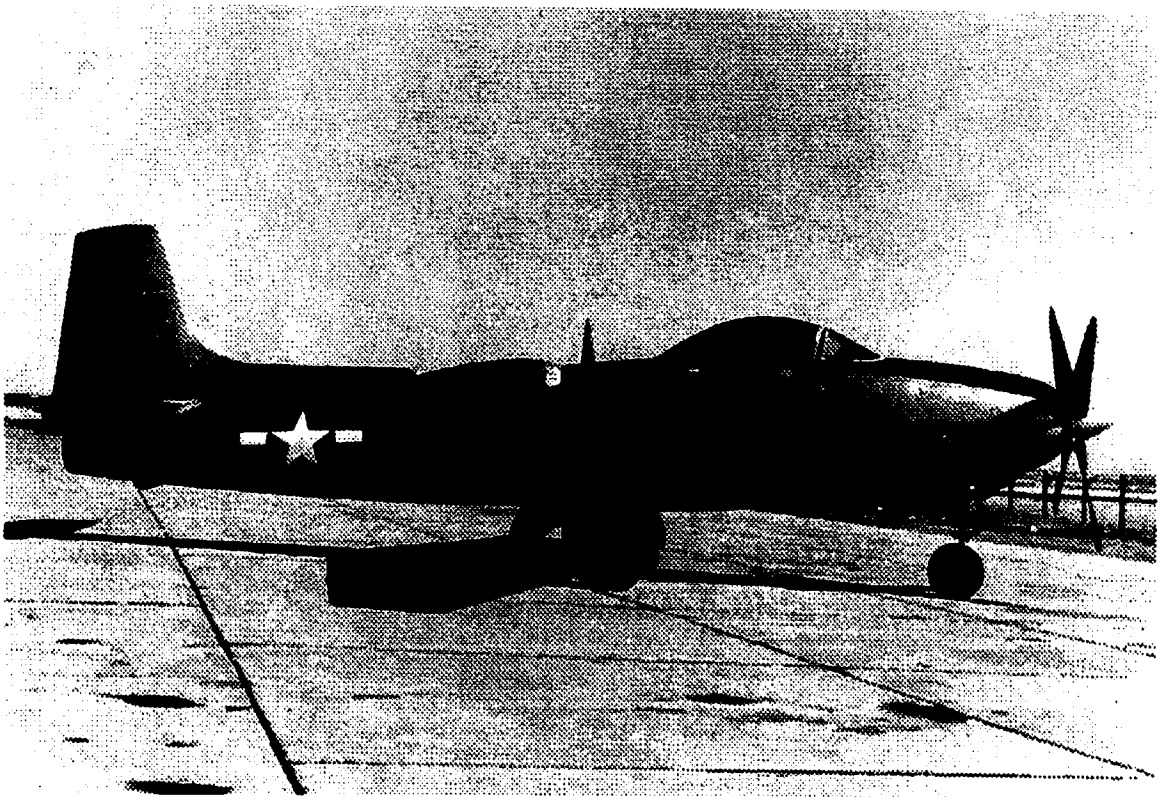
The Convair XP-81. The intakes for the rear mounted jet engine can be seen behind the cockpit, and the jet exhaust opening below the tail. Photo credited to January 1946 issue of ***Air Force***, dated 11 February 1946. (National Archives, Photographic Division, Box 2030, Number 30222)

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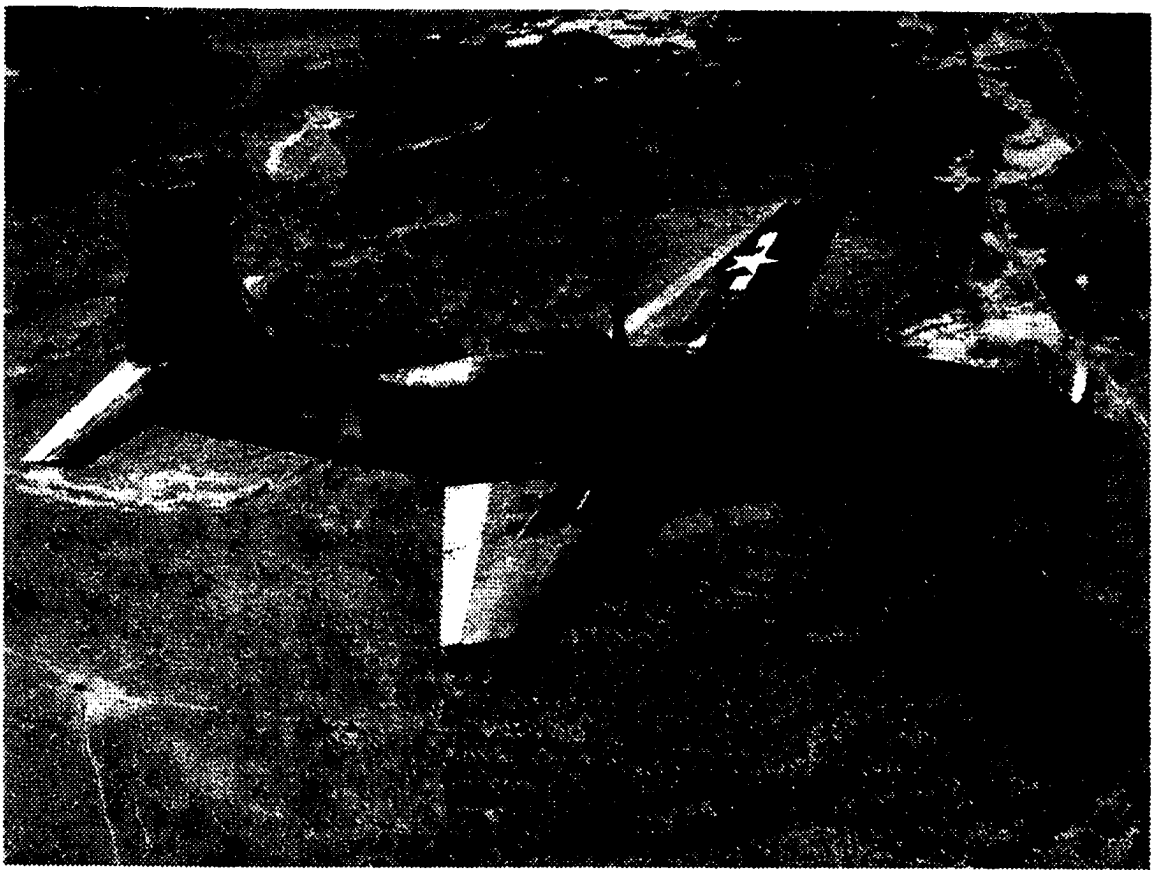
The XP-81 from the front. The air intake can be more clearly seen behind the cockpit. Photo credited to January 1946 issue of ***Air Force***, dated 11 February 1946. (National Archives, Photographic Division, Box 2030, Number 30223)

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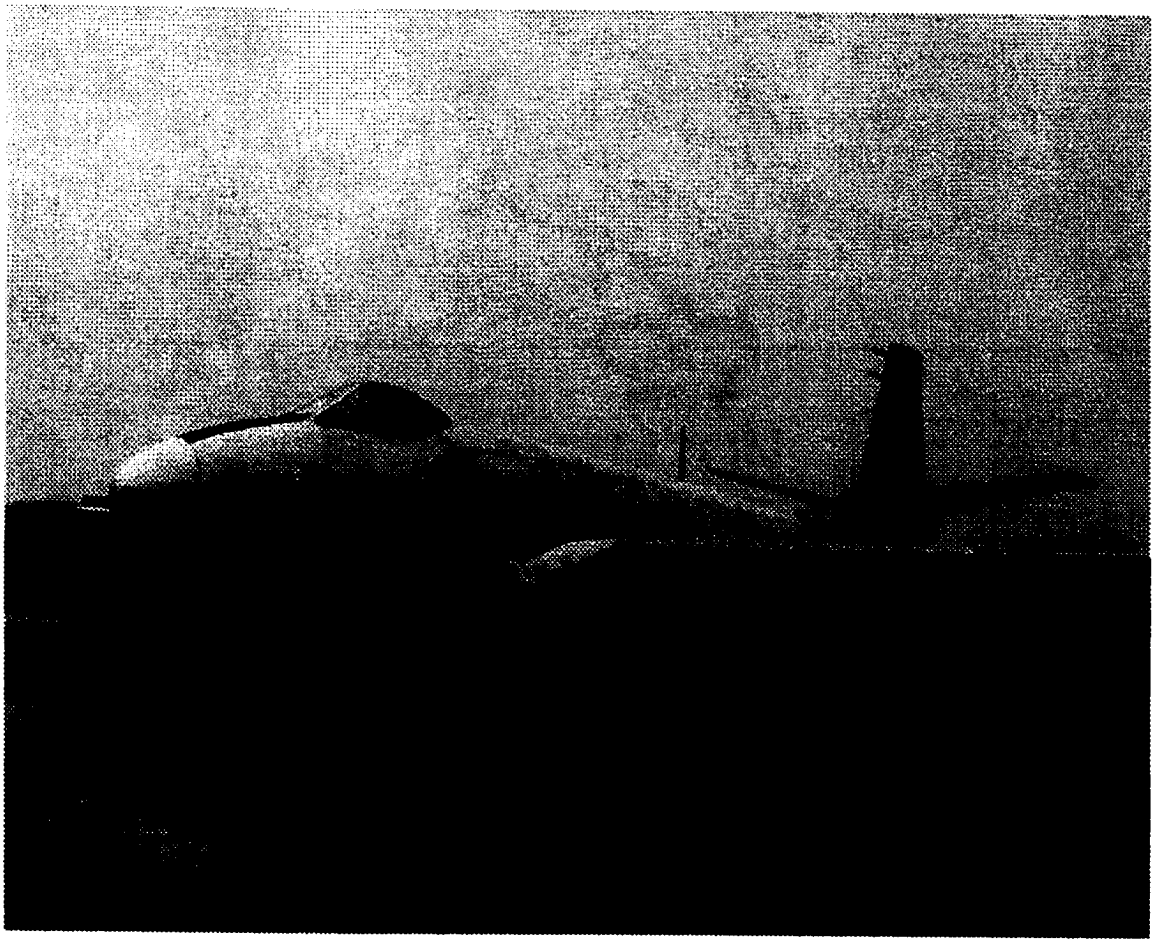
A side view of the XP-81. The hybrid nature of the plane can be seen clearly from this view. Photo credited to Wright Field, dated 19 March 1946. (National Archives, Photographic Division, Box 2030, Number 30226)

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The XP-81 in flight. Despite the plane's size, it retains a fairly sleek look. Photo credited to Consolidated Vultee, dated 19 December 1949. (National Archives, Photographic Division, Box 2030, Number 30229)

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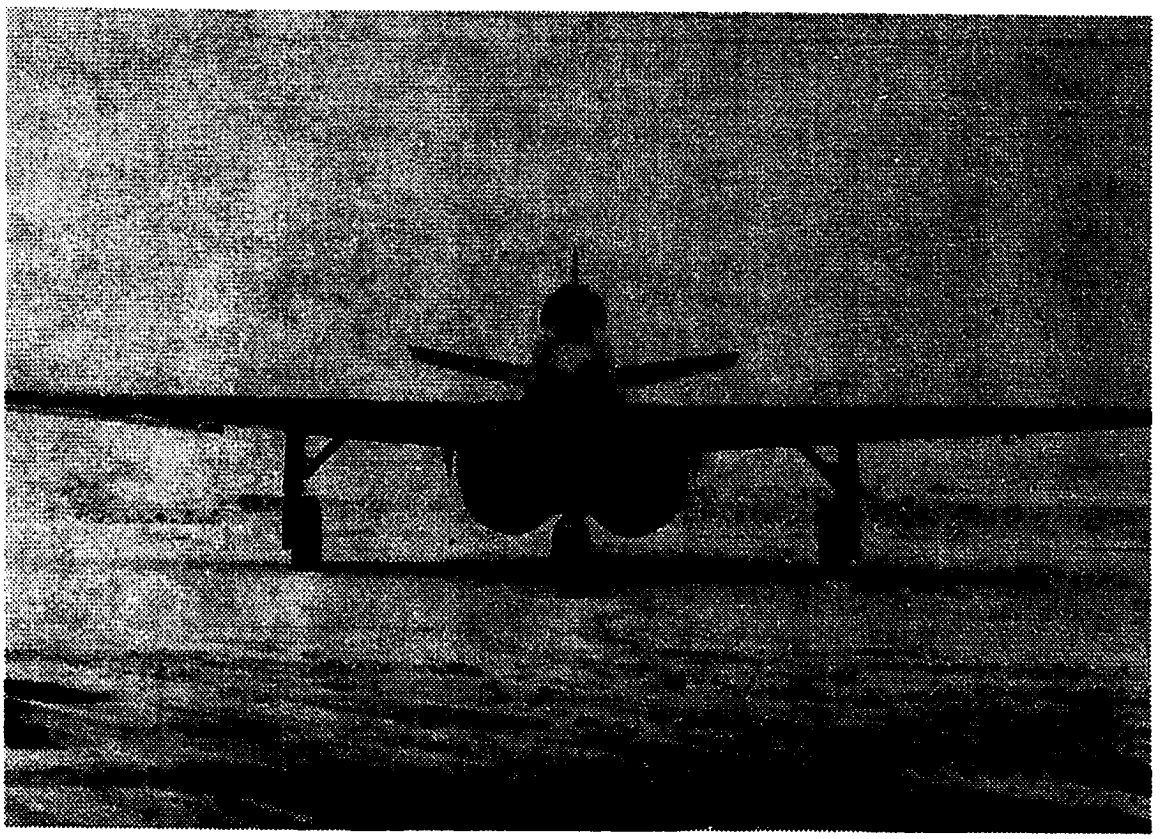
The Bell XP-83, the P-59's "big brother". Photo credited to Bureau of Public Relations, dated 22 October 1945. (National Archives, Photographic Division, Box 2030, Number 30262)

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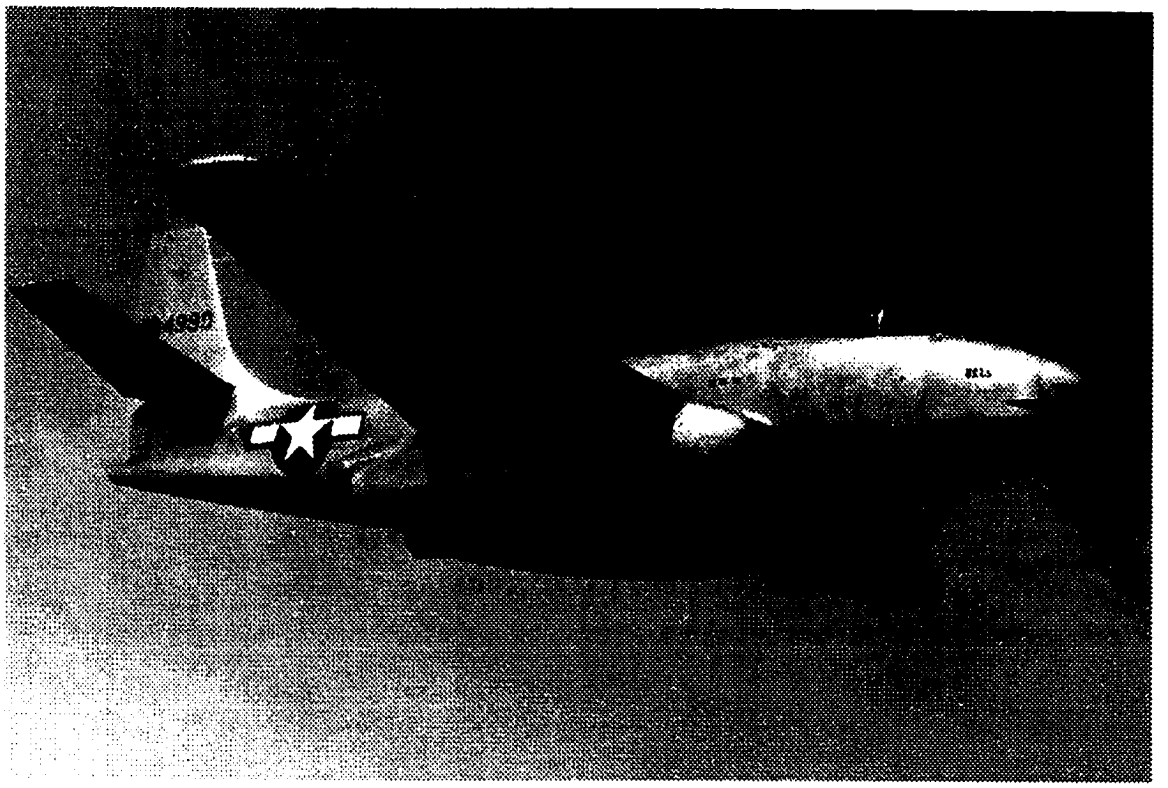
The sheer size of the XP-83 is evident in this photo. Most of the enormous fuselage is devoted to fuel storage. Photo credited to Bureau of Public Relations, dated 22 October 1945. (National Archives, Photographic Division, Box 2030, Number 30263)

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The close kinship between the XP-83 and the P-59 is perhaps most evident in this photo. Compare this to the similar view of the P-59. Photo credited to Wright Field, dated 12 December 1945. (National Archives, Photographic Division, Box 2030, Number 30266)

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The behemoth XP-83 in flight. The larger size of the engines, compared to the P-59, is apparent from this angle. Photo credited to January 1946 issue of ***Air Force***, dated 22 October 1945. (National Archives, Photographic Division, Box 2030, Number 30269)

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"It was expected that reciprocating engines would continue to be used in cargos, trainers and helicopters for some time to come, but that fighters and bombers of the future would probably use jet and rocket propulsion exclusively."
Historian Doris A. Canham, writing about the development of American fighters at the end of World War II[1]

Chapter 6
Post-War Influences on Jet Development

The Second World War had given birth to the jet fighter, and the technological advances and totality of this conflict had shaped the early development of this new weapon. A number of unusual and even unique circumstances created by the war exerted a major influence on America's jet fighter programs. It is important to recognize and briefly discuss these factors before moving on to consider the effect of the post-war environment on American jet fighters.

Perhaps the most obvious and important of these wartime factors was the extreme urgency attached to the jet fighter program. The United States was a relative latecomer to the idea of jet propulsion. Once the Air Force was made aware of the potential of this new power plant, they became committed to the idea of using it to produce a revolutionary new fighter airplane. The first attempt to do so, the disappointing P-59, was initiated less from a perceived need than the simple desire to use the technology, and a desire not to lag behind the British.

This commitment was transformed into a near obsession as news of German developments in the field became known to the Allies. American Air Force leaders were deeply concerned about the potential of German jets to disrupt or even halt the strategic bombing offensive over Europe. Given the poor performance of the P-59, it was considered essential to produce a high speed jet as soon as possible. This, of course, was the impetus for the P-80 program. The lack of an American jet fighter to counter the threat of the German jets was seen as a devastating

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vulnerability, and it resulted in the granting absolute priority to the P-80 program. During the entire war, the only other weapons program to be granted an equivalent priority was the atomic bomb and its delivery system, the Boeing B-29 Superfortress.[2]

Once it became obvious that the P-80 had the level of performance the Air Force was looking for in a jet fighter, this urgency became the driving force for the program. This resulted in an extremely demanding development/testing/production schedule for the plane, with a wide variety of attendant problems. These problems produced accidents and fatalities during the operation of the first P-80s. Even during wartime, a prototype that experienced a series of fatal accidents resulting from the failure of the aircraft would normally have halted the testing and development, until the problems could be analyzed and solved. The urgent demands for a jet fighter precluded this approach, however, and the P-80 program forged ahead at full speed regardless of such difficulties.

Under almost any other circumstances, such an attitude on the part of the Air Force would have been seen as nearly criminal in its disregard for life. During the largest war in history, in which thousands of Americans lost their lives in flying accidents during military training, it was barely noticed. In fact, given the extreme urgency and accelerated pace of the wartime development of the P-80, the program was remarkably safe and successful. The P-80 program was exploring not just one but two separate unknown realms of aviation - jet propulsion and high speed flight. Both fields were challenging and filled with largely unanticipated problems. Taking all this into consideration, it is a tribute to Kelly Johnson's talents and to his design for the P-80, as well as the skill of those participating in the testing process, that the program proceeded as well and as safely as it did.

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As discussed earlier, the urgency surrounding the P-80 program eventually came to have a life all its own. By early 1945, it should have been obvious that the circumstances which had prompted the Air Force's desperate need for the P-80 had been altered enough to reduce or even eliminate that urgency. Yet the Air Force only increased its demands for P-80s, and grew ever more frantic over delays in production. This same urgency also carried over to the other jet fighters initiated during the war - the P-84 and P-86. As long as the war lasted, the jet fighter was one of the most important and desired pieces of military hardware in America.

Another aspect of the wartime jet development was the extreme secrecy surrounding the efforts. Secrecy has been a part of military operations from time immemorial, but it is usually focused on such areas as strategy and battlefield maneuver. Secrecy concerns over the weapons themselves was largely a product of the scientific and industrial revolutions. The rapid advance of knowledge and manufacturing capabilities meant that devastating new weapons could be designed, produced and used to equip an army in a very short time. If these weapons had capabilities unknown to the enemy, they could be used to inflict decisive defeats on him - such was the theory, anyway.

This theory has tended to founder on a basic element of human nature. Essentially, the more people who know a secret, the less likely it is to remain secret. Yet, in order to design, build and distribute the secret weapon, an ever-larger number of people have a need to know about it. At some point, usually quite early in the process, the weapon ceases to be a secret. All of this is, of course, well known to military leaders. The quite natural (and largely futile) impulse on the part of military organizations to delay this revelation as long as possible has led to some illogical and even counter-productive behavior. The British refusal to allow their jet fighter, the

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Meteor, to operate over enemy territory despite the fact that the Germans had been conducting combat jet operations for almost a year, is a case in point. And even when the effort to preserve the secrecy of a new weapon works, the results are often not what the planners anticipated.

One of the more striking examples of the attempt to preserve the secrecy about a weapon actually being so powerful and effective as to inhibit its use in combat was a late 19th century French gun known as the *mitrailleuse*. This was a multi-barrel rapid-fire rifle-type weapon, which had the potential to vastly increase the firepower of the French army. Unfortunately for the French, the potential of this new weapons was so great that the high command decreed that only a small number of specially trained men could know about and operate the weapon. This not only limited the ability of the French Army to deploy the gun in combat (lest some unqualified person find out about it) but prevented them from conducting thorough studies of the weapon and determining how best to integrate it into their battle plans and strategies.

As a result of this obsession with secrecy, the weapon had virtually no impact on the fighting during the Franco-Prussian War, despite being available in quantity to the French Army before the war began. Since the Prussians were almost completely unaware of this weapon, it could have been used with devastating effect on an unprepared opponent. Unfortunately, the weapon was almost as unknown to the French army, as a result of its "top secret" status. This meant that it was used only rarely in battle, and then generally in such a hesitant and uncertain manner as to virtually negate all of its advantages.

Although American wartime jet fighter development was not restricted to quite that degree, there is no question that secrecy was a key element of the various programs. This began with the design and construction of the aircraft themselves, with the various companies essentially

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creating separate, "secret" divisions to handle the projects.

> At the outset of the program, Bell had realized that a separate area for the engineering and shop would be necessary for the XP-59 effort....All entrances to the building were guarded around the clock and special identification passes were required for entrance to the building. To further insure security, the metal window frames were welded shut and the lower window panes (even on the second floor) were painted over.[3]

At Lockheed, a similar secret division, although much less formal than that of Bell, actually became a permanent and highly successful element of the corporation, in the form of the famous "Skunk Works."

Likewise, all the early flight testing of the jets was performed at a facility as remote and isolated as possible - Muroc Dry Lake. There is no question that the hard, dry lakebed was an excellent surface from which to conduct flight tests, and its location in a barren desert meant that there were few prying eyes about. These qualities have meant that the facility, now named Edwards Air Force Base, has continued to be a major testing site for new and experimental aircraft. Even with this isolation, additional measures were taken, such as the fake propeller attached to the XP-59A prototype when it was towed through an area where it *might* be glimpsed by a civilian. This secrecy was imposed even at the cost of serious risk to those participating in the testing of the aircraft, as when Jack Woolams had to land an XP-59A in zero visibility in the teeth of a howling sandstorm, because he was forbidden by security regulations from attempting to land at a facility where the plane might be seen by an unauthorized person.

These secrecy measures were largely successful, and information on American jet fighters remained tightly restricted during the war. Even after the existence of jet-propelled fighter aircraft was revealed to the public, very little additional knowledge was passed on, save when a jet

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plane broke some performance record. Ironically, much of this secrecy was unnecessary, as there was little about America's wartime jet fighters, besides the engines themselves, that could be considered "new" technology or engineering. And since both Germany and England had been involved in researching and designing jet engines well before the American efforts, this left American companies in the unenviable position of having to play "catch up." Under these circumstances, the desire for secrecy was probably unnecessary and quite possibly more harmful than helpful to America's wartime jet development. Still, it is much easier to make such judgements in hindsight than at the time, and no one was likely to argue with the Air Force when they insisted on extreme secrecy for the jet projects.

There was a final factor that influenced American wartime jet development - America's wealth. The United States was the "Arsenal of Democracy," producing everything from giant bombers, rifles, and merchant ships, to trucks, aircraft carriers, and tanks in enormous quantities. American industrial output was so prodigious that the country was able to equip not only its own armed forces, but to supply enormous quantities of equipment to its allies as well. By the end of the war, many of the tanks in the British Army were American-built Shermans, and the Royal Navy equipped its aircraft carriers almost entirely with American-built warplanes. The men and supplies that transported the Red Army to victory were carried largely by American-built military trucks.

Despite this avalanche of industrial output, America still had the resources and wealth to build the world's second largest and ultimately most successful wartime jet aircraft program from scratch in just a few years. The British invented the jet engine and had a jet powered airplane flying before the United States was even aware of the existence of such a power plant. Yet their

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limited resources allowed them to produce only a small number of a single type of jet fighter, with one other design in development. The Germans, with an even greater technological lead in jet propulsion, did manage to design, produce, and operate small numbers of several jets. Yet the shortage of a number of critical raw materials crippled the German jet programs, regardless of the technical brilliance of their designs.

Perhaps the best illustration of the rapid advances in American jet aviation is in the engines themselves. Starting from a few underpowered sample engines provided by the British, American industry made such rapid progress increasing the power and reliability of the jet engine that even Frank Whittle, on a consulting visit to America, was taken aback. "...Whittle had been impressed by the vitality and breadth of vision incorporated in the American system, once his project had been accepted....The Americans generally were astounded at the parsimonious attitude of the MAP towards the work of Power Jets."[4] Improved American versions of Whittle's designs rapidly surpassed all other jet engines in power output. The most powerful jet engine utilized by both British and German aircraft during the war produced approximately 2,000 pounds of thrust. Aside from the P-59, all wartime American jet aircraft were designed with 4,000 pound thrust engines, while European models of equal power were still in the design stage.

Along with the industrial strength and abundant resources of the American economy must be considered the truly staggering amounts of money made available to fund American jet research and development during the war. Frank Whittle had to build his first test engines in an abandoned factory with private funds, due to lack of interest and shortage of funds on the part of the RAF. In the United States, brand new factories were built solely to design, test, and build jet engines. The Air Force itself had virtually limitless funds for projects it considered essential. The

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Air Force purchased fifty P-59B aircraft, even though they considered them unacceptable for combat, just to use them as transition trainers.[5] And while the XP-80 and XP-80As were still making their test flights, the Air Force ordered almost 10,000 of the production P-80A aircraft.

Nor was this the end of Air Force spending on jet projects. Before the war ended, the Air Force had ordered 100 P-84s from Republic, before the prototype had even flown, and had ordered prototypes of the North American XP-86. To this can be added the half dozen or so jet prototypes discussed in previous chapters. Yet this impressive output of jet designs, exceeded only by Germany, did not interfere with the production of America's aerial armada at all, while Germany's frantic efforts to produce a war-winning "wonder weapon" were a serious financial and economic distraction for her aviation industry. The political, economic and military infighting over the Me 262 program is perhaps the best example of this disruption. America's early jets were funded by enormous amounts of money and resources.

All of these developmental factors would be altered to some degree by the end of the war and the realities of the new post-war world. Other elements would also enter into the equation of jet fighter development, some of which had little or no direct connection to military aviation. Various influences would combine to shape the future of American jet fighter development.

The end of the war removed the primary rationale for the overwhelming urgency the Air Force attached to the development of jet fighters. Without even the minimal threat of the remnants of the Axis air forces, it was impossible for the Air Force to justify the breakneck pace of jet development and testing, especially in light of well-publicized accidents such as the one that killed America's leading fighter ace, Major Bong. The various design and testing programs were therefore scaled back to a pace which emphasized safety and fully-tested designs, rather than the

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earlier emphasis on producing as many jet fighters as fast as possible, and damn the consequences.

It should be noted, however, that the less frantic pace of development did not mean that the Air Force lost any of its commitment to the concept of jet aviation. On the contrary, the Air Force appears to have embraced jet propulsion with all the fervor of an atheist who has found God. From this point on it was jet power or nothing. Every single piston-engined fighter plane on order by the Air Force was simply canceled, save only the stop-gap all-weather F-82 Twin Mustang. Only a small number of F-82s were ordered, and they were withdrawn from active service as soon as they could be replaced by jets, even if the jets replacing them had no real performance advantages (and in the categories of combat range and endurance, considerably poorer performance).

There is no question that jet engines offered much greater long-term development potential and would eventually provide a far more powerful and efficient source of power for fighter planes. However, at the end of World War II jet technology was still in its infancy, and although jets could provide the power for higher speeds than piston-engined planes, in certain other respects they were inferior to piston engines. Piston engines were a mature, well developed and understood technology by this time, while jet engines were temperamental, unreliable and short-lived, even by the harsh standards of military aviation. Also, the switch to jet propulsion would require retraining all the Air Force's maintenance staff, as well as a complete restructuring of its supply system.

Given these circumstances, there were many even in the Air Force itself who questioned this wholesale adoption of jet power. It was felt that, for certain missions such as tactical ground attack, the early jets were in fact inferior to certain piston-engined planes such as the P-47

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Thunderbolt. The following exerpt from the report of Air Proving Ground Project No. 6478-4-5, *Operational Suitability Test of the F-84B Airplane* states the concept explicitly: "Jet aircraft, as typified by the F-80 and F-84, have less utility of employment than conventional aircraft; ie., excessive fuel consumption, especially at low altitudes, severely limits the tactical utilization of jet aircraft."[6] These issues were debated and written about by students at the Air War College at Maxwell Air Force Base in Alabama during the late 1940s, but there is little evidence that such debate and questioning affected the high command's decisions regarding the wholesale adoption of jet power.[7]

It is this author's opinion that the Air Force's fixation on jet power following the war arose at least in part, from the very nature of the Air Force itself. Advanced technology is more central to the very existence of the Air Force than any other service. The ships of the Navy and the guns of the Army are simply more refined versions of equipment that has existed for centuries and even millenia. Even submarines can trace a military lineage back several hundred years to primitive ancestors. The technology that allows an air force to function, in contrast, is less than a century old, and has changed, evolved, and improved almost constantly since its inception. What was cutting-edge technology one year was dated in only two or three years, and obsolete in less than five. Indeed, the careers of a number of prominent World War II Air Force generals began when they learned to fly airplanes built by the Wright brothers (and in some cases, taught by the Wrights themselves) and ended when they commanded supersonic jet fighters and intercontinental jet bombers.

By these standards, then, the Air Force has essentially been conditioned to accept new technology as inherently superior to old technology. It generally does not matter if the old

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technology is still capable of performing the job it was designed to do. Newer equals better. Jet engines, being newer and more modern, were apparently seen by many in the Air Force as inherently superior to piston engines, even in their infancy when they still had numerous developmental problems to overcome. Indeed, following World War II no other military aviation organization in the world was as fixated on jet engines as the United States Air Force.[8]

The secrecy under which jet fighters were developed continued, although it was less stringent. The earliest efforts at secrecy had been aimed as much at hiding the existence of jet propulsion as at the technical data from the aircraft themselves. By the end of the war, jet power was public knowledge, obviating the need for the strictest security measures - no more fake propellers! Although secrecy continued to shroud the various jet fighter programs, this was at least in part a simple reflex on the part of the military conditioned by a massive global war. Other aspects of post-war security were more commercial in nature - an attempt to prevent competitors from discovering important and potentially profitable technical information. Not until the Cold War began in earnest, with the detonation of the Soviet atom bomb, the Red Scare, and well-publicized incidents of communist espionage would a recognizable and dangerous enemy also motivate secrecy surrounding jet development.

It was the last of the wartime factors - the bottomless budget - that was altered the most drastically following the end of the war. America has a long tradition of suspicion and mistrust of the military, save during wartime. For most of our nation's history, this has left America with a peacetime military that was almost ridiculously tiny by the standards of most nations. The price in confusion and lost time needed to mobilize a large military during our infrequent large wars was considered an acceptable price to pay by most Americans for a small and non-threatening military.

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This attitude also meant that, when one of those large wars ended (and sometimes even before it ended), one of the American public's first and strongest reaction was to "bring the boys home." An army which may have numbered in the millions would be dismantled and sent home far more quickly than it had been raised. The United States had no need or tradition of maintaining any sizeable military force during peacetime, due in large part to the sense of security caused by the two oceans separating America from any militarily significant powers.

Air Force generals were well aware of this attitude as the war drew to an end. There was considerable apprehension among senior officers about the ability of the Air Force to function effectively, or even to survive, during the anticipated post-war downsizing. The abrupt and largely unexpected end of the fighting almost certainly increased the public's desire to dismantle the armed forces. America's enemies had been not only defeated, but literally destroyed. What need did the nation have for a large and expensive military?

The Air Force had, for some time, been attempting to calculate its post-war needs. Dependent as it was on complex technology, the Air Force could no longer exist as a skeleton force in peacetime, to be filled out by short-service conscripts and volunteers during a war. The Air Force hoped (somewhat unrealistically) to maintain a force of 105 groups, and considered a force of 70 groups to be the absolute minimum to fulfill their obligations.[9]

These needs were considerably greater than most of the general public would have thought, for a number of reasons. One of those reasons was the fact that American military forces were no longer limited to deploying in the continental United States and a few small overseas possessions. For the first time in a century and a half, we had made significant political and military commitments to other countries - the "entangling alliances" that George Washington had

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warned about, and American politicians had carefully avoided since his day. But the need to provide occupation forces for defeated nations, and to provide military security for badly battered allies, meant that we could not bring all of the boys home.

The general public, including a large number of active-duty servicemen, did not share the same concerns, and so the American Army Air Forces, which had numbered over 2.25 million during the war, were slashed to just over 300,000 less than two years after its end. As the size of the military shrank, so did its budgets. Although the personnel cuts came first, the budgets fell even faster than the numbers of personnel. The Air Force, having calculated a minimum of 70 groups as necessary to meet all its mandated responsibilities, was eventually forced to try to do so with little more than half of this number.[10] Even worse than the simple arithmetic was the drop in combat capacity of the surviving groups. "On August 15, 1945, there had been 218 AAF groups of all types, most of them ready to fight. By December 1946, sixteen months later, there were only 52 groups remaining in the AAF, and of these only *two* were combat ready."[11]

There was never any real danger that existing jet development programs would be cancelled, even with the vastly reduced funding available. They were simply too important to the Air Force for that to be considered. But this did mean that any future programs, or even major modifications to existing ones, had to be considered very carefully from a budgetary standpoint, as well as a technological one. During the war, quite a large number of experimental combat aircraft had been ordered by the Air Force. Given the millions being spent for other aircraft, what was a few hundred thousand to try out some new designs? But with the harsh budgetary restrictions of the post-war military, new projects had to be carefully considered and have a reasonable prospect of success in order to proceed. Between 1940 and 1945, the United States

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Air Force ordered no fewer than 44 different fighter aircraft, either as production machines or evaluation prototypes. Between 1946 and 1950, the number of similar aircraft dropped to thirteen - and this number included several aircraft, such as the P-80 and P-82, which had begun their production runs during the first half of the decade. So if the birth of the American jet fighter had been eased by a virtually limitless flows of money, its early growth and development was limited by the lack of funds.[12]

These were not the only factors complicating the development of jet fighters in post-war America. There were a number of larger issues involving the Air Force and the Armed Forces in general that would make their influence felt in a variety of ways. These problems dealt with everything from debates about the type of fighter aircraft that should be used by the Air Force, up to the nature and even existence of the Air Force itself. These issues will be examined beginning with the broadest and working to the most specific.

One factor of the post-war American military was the status of the Air Force. Since its creation, the air force had been a subordinate branch of the United States Army. Air force officers had been dissatisfied with that status for many years, and had sought for a means to win separate, co-equal status for their service. Strategic air bombardment, which was advocated more forcefully in the United States than by any other major military power during the 1930s and 40s, was adopted by the American air force primarily because it gave the air force an important military mission that could not be duplicated by any other branch of the service. Indeed, during the war, strategic bombing came to be seen by most senior air force officers as the only worthwhile mission for its aircraft. The howls of protest from Air Force generals when their precious strategic bombers were diverted to attack the French rail net before the D-Day invasion,

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or to provide direct support for major ground attacks, were amazing in their volume and vehemence. The addition of the atomic bomb to the Air Force's strategic arsenal only strengthened their devotion to the cause. The results of the war, in the eyes of the Air Force, completely vindicated their beliefs in the effectiveness and necessity of strategic air bombardment, and by extension, of the Air Force.

By the end of the war, Air Force generals were openly campaigning for independence for their service. The publication of the War Department's Field Manual 100-20, *Command and Employment of Air Power* in July 1943, was seen by many army officers as the Air Force's "declaration of independence." This manual stressed the co-equality of land and air power, and argued that the first and most important step in any military campaign was to win control of the air. The wartime contributions of the Air Force, and some serious negotiations produced the desired result, and in September 1947, the United States Army Air Forces became simply the United States Air Force. In the process the Air Force acquired their own uniforms, service academies, and budgets. But this was not the only military shakeup to occur in the wake of the war.[13]

During the war, the argument had been made, from both within and outside the military, that the existing command structure was too cumbersome and too prone to disagreement and argument. The relatively smooth functioning of the Joint Chiefs of Staff occurred despite the command structure, not because of it. Both the Army and the Navy were completely separate and co-equal, both militarily and politically, answering to no one but the president. It was proposed that all the branches of the armed forces be integrated as a single military organization. This idea was vigorously, even violently opposed by the navy, which harbored a not entirely groundless fear

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that the army and especially the air force would claim that the navy was now obsolete, and attempt to disband it. The final compromise solution to this problem left the services (including the new Air Force) separate but standardized and unified much of the administration and logistics for them, and put their political oversight under a single Secretary of Defense, with Assistant Secretaries for the various branches, rather than the separate Secretaries of War and the Navy that had existed up until that time.[14]

The Air Force, having attained independence, proceeded to develop a new organization to match its chosen goals and responsibilities. Rather than the old war-time system of numbered air forces (5th, 8th, 9th, 15th, etc.), the new Air Force was divided into commands. By far the largest and most important of these new commands was SAC - the Strategic Air Command. This was the portion of the Air Force dedicated to strategic / nuclear bombing. Air power theorists had claimed for decades that air power alone could win wars, and now the Air Force felt they finally had the technology to fulfill that claim. By far the largest share of the budget, resources and prestige of the newly-independent Air Force went to this command. Large, long-range strategic bombers were far and away the most important planes in the post-war Air Force, with all other types of aircraft, including fighters, relegated to supporting roles.

The other combat commands were TAC (Tactical Air Command - fighters and light bombers), and ADC (Air Defense Command - fixed defenses and interceptors). Non-combat commands included AMC (Air Material Command - research and development), ATC (Air Transport Command - supply and maintenance), APGC (Air Proving Grounds Command - testing), and ATC (Air Training Command). All of these commands were clearly subordinate to SAC in terms of importance and mission. Not only were the other commands subordinate to

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SAC, but their missions were often defined in relation to their impact on SAC. The primary role of fighters, for instance, was either to protect or destroy strategic bombers, with any other tasks they might perform seen as far less important. SAC also got the pick of the facilities, personnel and equipment available to the Air Force. All of this would affect the development of jet fighters.

As the Air Force emerged as a separate service, one of its crucial tasks was to formulate an official doctrine, a set of policy guidelines that would shape everything from aircraft design to combat formations. This was not an easy task, as recounted by Conrad Crane:

> The new service also had great difficulty writing its own doctrine. War Department Field Manual 100-20, *Command and Employment of Air Power*, had been written in 1943 and emphasized the coequality of land and air forces. It needed to be replaced by a new basic doctrinal manual for the air services that would serve as the foundation for a series of supplementary publications detailing strategic air, air defense, theater air, and air transport operations. Attempts to centralize doctrinal responsibilities at Air University were resisted by some field agencies, especially Tactical Air Command, and significant disagreements arose within the service about the content, style, and format of Air Force manuals. Opinions were particularly divided over the differentiation between strategic and tactical air missions and the proper role for theater air forces. Because of these problems, plus a slow review process when drafts reached the Air Staff in Washington, the new capstone Air Force Manual 1-2, *United States Air Force Basic Doctrine*, was not published until 1 April 1953.[15]

So, for the entire post-war period covered by this study, the Air Force had no official doctrine to shape its operations, procurement or tactics. Most senior Air Force officers were fairly content with the basic doctrine that had been used during the war, with its emphasis on strategic bombardment. Exactly where the new jet fighters would fit into this doctrine was a vexing question, however.

Although not sanctioned as official doctrine, the Air Force did produce a series of

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guidelines defining the roles of jet fighters during this period. These guidelines were not really intended to cover the older piston-engined fighters. Rather, they were to be applied to jet fighters, both existing and new designs. These guidelines specified four primary roles or categories for jet fighters. These roles included Penetration, Interception, All-Weather, and Internally Stowed, or Parasite fighters. Each category was intended to be exclusive - that is, a fighter designed as an All Weather plane would not be expected to operate as a Parasite or Penetration fighter. Because these guidelines were the defining element of most of the post-war jet projects initiated by the Air Force, it is worth discussing them in some detail.[16]

The Penetration fighters were perhaps the closest to the earlier concept of a generic fighter plane. Penetration fighters, as the term implied, were intended to operate in enemy territory. The most important characteristic these planes were to possess was a substantial combat radius. Combat radius can be defined as the greatest distance a plane could fly from its base, with the expectation of combat during the flight, and then return safely to the base. Since combat uses far more fuel than simple cruising, the maximum combat radius is often considerably shorter than the maximum range of the same aircraft. Range is defined as simply flying from one point to another, using the most efficient fuel settings.

Penetration fighters were intended to be the most versatile of the new jets. Their primary task would be the escort of strategic or tactical bombers, to protect them from enemy fighters. But penetration fighters would also be considered for such missions as photo reconnaissance, engaging enemy fighters, interdiction of enemy supply lines, tactical bombing to support ground troops, and fighter sweeps and other air superiority tasks. In addition to a substantial combat radius, such aircraft needed a respectable speed, the ability to carry a variety of external stores,

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such as fuel tanks, bombs, or rockets, and good maneuverability to engage enemy fighters.[17]

All of the existing American jet fighters (P-80, P-84, P-86) were classified as penetration fighters, although none of them had the extended combat radius that the Air Force really wanted. Therefore, the Air Force released its desired performance characteristics, and asked companies to submit designs. As a result of following this process, two designs were selected to be built as evaluation prototypes - the McDonnell XF-88 and the Lockheed XF-90. A third, the North American YF-93, was added later. Testing took place during the last few years of the 1940s, but the evaluation and decision making process were interrupted by the Korean War. When the war was over, the Air Force returned to the penetration fighter concept, with the lessons learned from that conflict to help them evaluate the concept.[18]

The second class of new jet fighters was the interceptor. The primary, in fact almost the only task of an interceptor was to engage and destroy enemy bombers, especially the large strategic bombers. The earlier Lockheed P-38 Lightning had originally been designed as an interceptor, and several of the wartime evaluation prototypes were also intended to be interceptors. In the event, only the United States and Great Britain utilized substantial numbers of large strategic bombers during the war, removing the need for an American interceptor.

With the end of the war, the increasing focus on the Soviet Union as a potential foe, and the Soviet Union's effort to acquire long range strategic bombers, resurrected the concept of the interceptor. Interceptors were intended to have great speed and rate of climb, and a very powerful armament. These characteristics came from the fact that interceptors would be required to take off on short notice, climb rapidly to the altitude of the incoming bombers, and then quickly engage and destroy them. Other characteristics, such as combat radius, external storage capacity,

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or endurance were considered distinctly secondary to the primary mission of the interceptor.

For inspiration, aircraft designers turned to the one nation that had been forced to deal with large numbers of strategic bombers and had demonstrated some success at intercepting them - Germany. Although jet engines were capable of greater power and speeds than piston engines, they were still temperamental and relatively low-powered. Even the development of the afterburner, which dumped raw fuel into the exhaust gases, producing a vivid flame and a substantial increase in thrust, did not allow for the level of power needed for this task. To produce the exceptional speed and rate of climb the Air Force desired, the companies looked to the German wartime design that demonstrated both qualities - the Me 163 Komet.

Just as the Me 163 achieved its impressive performance by the use of a liquid-fueled rocket engine, so the two American interceptor prototypes used rocket power. Unlike the Me 163, however, they combined several rockets with a more conventional jet engine. Two companies built evaluation prototypes of rocket powered interceptors after the war: the Republic XF-91 and the Vultee XF-92. Both aircraft utilized a number of unusual and innovative design features, and were tested extensively, although neither was selected for quantity production.[19]

The third category for new jet fighters was that of all-weather aircraft. Prior to the Second World War, almost all aircraft, especially fighters, operated only during daylight hours in conditions of good visibility. To do anything else was an invitation to disaster. The development of such systems as aircraft lighting, radio navigation and especially radar all combined to allow the operation of aircraft in conditions that previously would have prevented them from flying. During the war, bombing at night became a regular practice by many of the belligerents. In an attempt to counter this practice, a number of nations developed radar-equipped night fighters, both to

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intercept night bombers and to protect them.

The same principle carried over into the post-war world. All of the previous American jet fighters had been designed for daylight, high-visibility operations. The Air Force felt a strong need for jet fighter aircraft that were capably of operating in various adverse weather conditions (the Air Force considers darkness a weather condition). This meant that the aircraft would have to be equipped with radar. As radar sets of the period were still quite bulky, as well as being complex and difficult to operate, it was wisely felt that the pilot would be unable to devote sufficient attention to operating the radar in addition to flying the aircraft. This necessitated the addition of an extra crewman to the aircraft, to operate and monitor the radar set.

Another important characteristic of an all-weather fighter was substantial endurance and combat radius. All-weather fighters had the most stringent combat radius requirements of any of the new jet types, 1,000 miles, greater even than penetration fighters. Speed was significant, but of less importance than to a penetration fighter, as all-weather planes were intended primarily to engage bombers, while the penetration fighters might also have to mix it up with enemy fighters. The extra crewmember and the massive fuel requirements for the inefficient engines meant that the prototype all-weather aircraft were immense by the standards of fighter aircraft.[20]

Two prototypes were evaluated by the Air Force, the Curtiss XF-87 Blackhawk and the Northrup XF-89 Scorpion. Two other all-weather aircraft was also tested, the Lockheed XF-94 Starfire and North American's YF-95, later the F-86D. The Starfire was an armed and radar-equipped version of the Lockheed T-33, itself a two-seat, dual control training variant of the F-80 Shooting Star, while the F-86D was a radar-equipped version of the very successful F-86 Sabre. Simpler and smaller than the other two aircraft, it also had the advantage of utilizing components

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from an already proven and reliable fighter, which would make it both easier and cheaper to manufacture.[21]

Finally the Air Force evaluated the internally stowed, or parasite fighter. This was a small fighter aircraft that would be carried inside a large intercontinental bomber, released to engage enemy aircraft, and then recovered by the bomber and returned aboard. The Navy had experimented with the concept in the 1930s aboard their airships, and the Air Force had first considered the idea in 1940, when fears of the collapse of England and the need to attack a Nazi-dominated Europe from North America led to the design of exceptionally large and long-ranged bombers. These aircraft would obviously fly well beyond any possibility of fighter escort, so the idea was to bring the fighter escort along with them. When it became obvious that Great Britain would not surrender, these plans were shelved.

With the war's end, and the increasing concern about the actions of the Soviet Union, the Air Force once again became interested in the potential of ultra-long range bombers. In addition to resurrecting and updating the XB-35 and XB-36, the two early war designs for ultra-long ranged bombers, the Air Force also initiated projects that would become the Boeing B-47 Peacemaker and Boeing B-52 Stratofortress intercontinental jet bombers. With these long-legged aircraft once again came concern over fighter escort, and the parasite fighter concept was also taken out and dusted off. Never more than a paper project earlier, it now became a full-fledged evaluation prototype.

Only one design was evaluated for the parasite concept, the McDonnell XF-85 Goblin. Obviously, the major design criteria for such an aircraft was small size, so as to be able to fit aboard a bomber. Other important characteristics included good speed and maneuverability, and

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respectable armament. As the plane was never intended to take off from the ground, and to land there only in an emergency, the heavy and bulky landing gear could be dispensed with. The result was a tiny plane, looking like an egg with stubby wings. The Goblin was tested extensively, and proved to be a surprisingly capable aircraft.[22]

Two other elements need to be kept in mind when considering the post-war development of jet fighters. Although not direct influences, these factors influenced not only jet fighters but all military aviation, and indeed all military activity during this period.

The first of these factors is the looming presence of nuclear weapons. Nuclear weapons exerted a massive though contradictory influence on military aviation during the second half of the 1940s. The use of nuclear bombs on Japanese cities had been pivotal in persuading the Japanese Empire to surrender to end the Second World War, and they were seen in America from that point on as war-winning weapons.

Nuclear weapons during this period were the subject of an odd kind of dualism. On the one hand, they were considered to be weapons of immense power, capable of single-handedly ending a war. On the other hand, they were also considered to be simply one more weapon in the arsenal, bigger and more powerful, perhaps, but still just another type of bomb. And bombs were meant to be used. Operation OLYMPIC, the planned invasion of the island of Kyushu, was to be preceded by the dropping of a number of atomic bombs immediately behind the beachhead.[23] During the Korean conflict, General Douglas MacArthur wanted to use "30 to 50" atomic bombs on Chinese cities to punish them for intervening, and to spread radioactive waste along the Yalu River to seal off Korea from China. Although MacArthur's plan was overly grandiose, both presidents Truman and Eisenhower seriously considered the use of nuclear weapons in Korea.

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Their use was rejected, not out of any great moral aversion to their use on the part of the American government, but because it was felt that the mountainous terrain in Korea would inhibit their effective use.[24]

The moral stigma of these weapons would only come later, helped, no doubt, by the massive power of the hydrogen fusion bombs, which made even the bombs dropped on Japan look like firecrackers in comparison. Of course, another possible reason for America's remarkable *sang froid* about the Bomb during the 1940s was the fact that it was the only country to have any. It is fairly easy to contemplate the immolation of one's enemies, when secure in the knowledge that one's own country is safe from similar harm. When the Soviet Union began to test and build their own nuclear devices, American politicians and military officers became much more circumspect about the possible use of such weapons.

During the 1940s, nuclear bombs were the ultimate weapon, and only the Air Force had any. In fact, intense competition over the deployment of nuclear weapons was one of the major points of contention between the various branches of the military during this period. The Navy wanted their supercarrier, the *United States*, primarily because it would be large enough to enable them to deploy nuclear-capable bombers from its deck. This inter-service competition would ultimately develop into the nuclear "triad" of bombers, land based missiles, and nuclear missile submarines, not to mention nuclear tipped artillery shells and short-ranged mobile rockets for the Army. But for the time being, only the Air Force, or more specifically, SAC, had nuclear weapons and the means to deliver them.

At least that was the theory. That, after all, was SAC's mission - to deliver rapid, overwhelming destruction to an enemy. The reality was a bit more uncertain. Although receiving

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the lion's share of the Air Force budget, SAC too felt the financial pinch. The massive new Convair B-36 Peacemaker began to reach operational status during this period, and there was always the effective Boeing B-29 Superfortress and its improved successor, the B-50. But the atomic weapons of the period were bulky and heavy, weighing at least five tons apiece, and neither the B-29 nor the B-50 could carry one without specific modifications. In fact, during the 1940s, only the 509th Bombardment Group, the same unit that had dropped the atomic bombs on Hiroshima and Nagasaki, had aircraft capable of delivering nuclear weapons.[25]

This meant that American military policy of this period, embodied in war plans HALFMOON and DROPSHOT, which relied on overwhelming nuclear annihilation as their primary element, was in fact largely a hollow bluff. The United States possessed only a small number of useable atomic warheads, and only a handful of crews and aircraft capable of delivering them. That wasn't even the worst of it. In 1948 SAC's new commander, General Curtis LeMay, tested all thirty of his nuclear-trained crews, and not one of them could deliver a weapon accurately on target under combat conditions. Although LeMay immediately set to work whipping his force into shape, it would be years before the idea of massive nuclear strikes would become a reality. And of course, by then the Soviets were building their own bombs and bombers.[26]

Despite this weakness, nuclear weapons remained the central element on American military policy during this entire period. In fact, the American monopoly on nuclear weapons was one of the main justifications for gutting the conventional military forces. Why did the country need to support a massive and expensive army and navy, when a handful of nuclear bombs could accomplish the same results for far less money? Of course, nuclear weapons are not very

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selective, and it eventually dawned on policy makers that nuclear weapons, far from being the answer to any military problem, were more of a weapon of last resort. After all, reducing Moscow to radioactive rubble in retaliation for a minor border incident was hardly an appropriate (or safe, once the Soviets deployed their own bombs) response. This incompatibility would eventually lead to the concept of MAD, Mutual Assured Destruction, and became a policy of deterrence, rather than use of the weapons.

These problems did not prevent the Air Force from paying a great deal of attention to the question of nuclear weapons. Two of the four fighter classes, interceptors and all-weather fighters, were intended primarily to destroy Soviet nuclear bombers. And the possibility of using nuclear weapons as something other than city-killers continued to draw interest. One of the major Air Force projects of the late 1940s was to produce a nuclear weapon that could be used tactically, delivered not by a massive bomber, but rather by a small and agile fighter plane. One of the planes in this survey, the F-84 Thunderjet, eventually became the first Air Force fighter to be capable of delivering a tactical nuclear weapon. Exactly what such a weapon would be used *on* was another, and far more difficult question, and one that was never satisfactorily answered.

Nuclear weapons were one half of the background picture in the later 1940s. Inseparably linked to the question of nuclear weapons was the gradual evolution of what eventually became known as the Cold War. (The exact causes of and blame for the development of the Cold War will no doubt continue to be debated for decades. Of concern to this study is the effect of the early Cold War on military affairs, especially jet fighter development.)

The Soviet Union occupied a confusingly ambiguous position in the eyes of the United States in the years immediately following the Second World War. During that struggle they had

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been America's allies, partners in the valiant struggle to destroy fascism and eliminate the menace of Nazi Germany. And as a result of that struggle, they paid an enormous price in lives and treasure lost, far higher than any other victorious nation. And for that Americans gave them admiration and respect.

Yet that respect was tempered by wary concern. Although Stalin had been on America's side during the war, he had earlier been allied with Germany for nearly two years. And he still was an absolute dictator, paranoid and ruthless. And he ruled over a nation that had included as part of its official government, until it was disbanded during the war as a gesture of reassurance, an organization dedicated to the destruction and overthrow of non-communist governments around the world.

Although American actions undoubtedly contributed to the growing tension between the two powers, Stalin's decisions after the war made it abundantly clear that he was determined to maximize the Soviet Union's power and prestige, and would let very little deter him. Since many of these choices set him on a collision course with American interests, it was perhaps inevitable that the two powers would end up facing each other in a confrontational manner. Of course, the American declaration of intent to "contain" communism no doubt confirmed to Stalin that his actions were necessary if his country was to survive. As a result of all this, two countries which had been close, if not exactly friendly, allies during World War II, had become, in less than five years, opponents on either side of a regional conflict in Asia.

Strangely, the early Cold War mattered very little to the American military during the immediate post-war years. Not that the American military was unaware of the potential threat posed by the Soviet Union. But the clash of ideologies (The Free World vs The International

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Communist Conspiracy) that would later make the Cold War such a tenacious phenomenon had yet to reach full impact. The American military did focus much of its attention on the Soviet Union, but not necessarily out of Cold War fervor.

The U.S. had emerged from the greatest war the planet had ever known in a position of immense military and economic power, and the only nation of even comparable power was the Soviet Union. The difference in power between these two nations and all the rest was so great that the term 'superpower' was invented to make the distinction plain. And the two superpowers automatically looked to each other as by far the greatest potential threat to their own power. This would have happened regardless of ideology. The nature of the clash between communism and capitalism simply intensified the process. Yet until the Berlin Crisis in 1948, the Soviets did little that was directly confrontational against the United States, which allowed for some hope that a reasonable settlement could be worked out.

So the American military did concentrate its attention on the Soviet Union during the immediate post-war years, but this was undoubtedly due at least as much to the fact that a military needs a credible enemy to validate its existence as it was to any perception of a "Red Menace." The simple fact was that the Soviet Union was the only power on earth with the muscle to make a respectable enemy. So efforts were focused around what were viewed as the most likely scenarios for engaging this prospective enemy - a massive conventional ground war in Western Europe, and the strategic nuclear bombardment of Soviet cities.

Another reason the emerging Cold War and the Soviet threat did not have an enormous practical impact on the American military in the immediate post-war years was that the American military lacked the strength, equipment, or budget to actually do anything about the Soviet threat

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even if it had wanted to. The massive drawdown of American forces after the war ended has already been mentioned. American military planners did consider potential conflicts with the Soviet Union, but generally lacked the resources to implement such plans. The weakness of the Air Force in that regard has already been discussed, and the other services were in comparable condition. During the Berlin Crisis, President Harry S.Truman "...told his advisors he would like to give the Russians hell, but Secretary of State George C. Marshall responded that he thought one American division in Europe was not an adequate instrument for even the threat of hell."[27]

The real savior of American military fortunes was, ironically, the Korean War. Beginning just before yet another round of slashed budgets and downsized forces, the Korean War saw a massive increase in military manpower, equipment modernization, and larger military budgets. Further, these augmented force levels largely remained in place even after the conflict ended. It is entirely possible that without the rude wake-up call of Korea, the American military might have eventually become so impotent and toothless that it would not have sufficed to deter later, even larger scale Communist aggression elsewhere in the world.

Focusing on the Air Force in particular, the first few years of the Cold War seem to have provided little specific impact. Although two of the new fighter classes, the interceptors and all-weather fighters, were designed to shoot down strategic bombers, this was largely an effort to defend against American-type technology and strategy. The Soviets possessed no long range strategic bombers of their own during this period, although they did eventually reverse-engineer the B-29 Superfortress and produce it as the Tu-4. However impressive this aircraft was by World War II standards, it lacked the range to strike at American targets from Soviet bases, unless used on one-way suicide missions.

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In fact, the Air Force in general does not seem to have been overly concerned with Soviet aircraft developments during this period. General American consensus, supported by combat records taken from the Germans, seemed to indicate that Russian aviation equipment was crude and lacked the performance of the latest German and American designs. The Soviet practice of simply taking German aircraft directly into their own air force immediately after the war certainly seemed to support that assumption. So although the Air Force tested captured German and Japanese aircraft, as well as the latest British designs, there does not seem to have been a great deal of urgency or concern over the lack of Russian models to evaluate. Given that the Soviet Union was the most likely opponent in a future conflict, that was a dangerous complacency.[28]

In fact, the Air Force seems to have regarded Russian aircraft with something close to contempt, simply assuming that their own planes would be technically superior. When coupled with superior American pilot training and doctrine, this would inevitably lead to crushing American air superiority. Thus the shock was all the greater in Korea when the Air Force encountered the swept-wing MiG-15, the latest Soviet jet fighter. They found it to be not only inherently superior the older straight-wing American jets such as the F-80 and F-84 that were then employed there, but at least the equal of America's latest swept-wing fighter, the F-86, when it was rushed there in an attempt to cope with the threat.

This was not the first time the American air force had underestimated an opponent with disastrous consequences. Japan had been dismissed as a second-rate, imitation great power in the 1920s and 30s. Then during the opening stages of Japan's attack on the western powers, a new and devastating fighter aircraft swept its opponents from the sky. The Mitsubishi *Reisen*, or Zero, proved to be one of the most successful of the early war fighter planes. Japan's inability to

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produce a late-war successor to it, and American pilot's eventual mastery of the Zero's weaknesses perhaps dulled the shock of those first rude encounters. But unlike the Zero, the MiG-15 lacked easily exploitable weaknesses, and remained a dominant presence during the entire Korean War.

Although during the later stages of the Cold War American weapons systems would be designed specifically to counter or negate specific Soviet weapons, the first few years of the Cold War seem to have exerted surprisingly little effect on the US military, beyond the knowledge that in a future war the Soviet Union would be the most likely opponent. Soviet fighters were easily dismissed as second rate equipment (after all, we had provided a great many of their fighters during the war) and the only large bomber that they had was in fact one of ours built in their factories. Not until Korea would this attitude begin to change.

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1. Canham ***Fighter Aircraft***, p. 97.

2. Brigadier General P.W. Timberlake, Deputy Chief of Air Staff, Washington to Assistant Chief of Air Staff, Material and Services, Washington, 30 January, 1945 ***P-80 Case History***.

3. Carpenter ***Flame Powered*** p. 19.

4. Golley ***Whittle*** p. 199.

5. The various P-59 prototypes cost approximately $4,000,000 to produce, and the initial contract for 100 production models came to almost $17,000,000 plus another $4,000,000 for spare parts. Unit cost of the production airplanes was approximately $125,000, compared to $50,000 for a P-51 Mustang. Even when 50 planes were cut from the production order, the cost of the contract only dropped by about $4,000,000, as various factors combined to make this a very expensive plane. So the United States spent approximately $25,000,000 on a plane that was never used in combat, and used only in limited fashion as a trainer. That same amount of money would have bought about 500 P-51s. Inter-Desk Correspondence, Colonel M.S. Roth, Chief, Aircraft Project Section, Wright Field to General O.F. Carroll, Chief, Engineering Division, Wright Field, 10 April 1944; Letter, Bell Aircraft Corporation to Contract Officer, Wright Field, 1 November 1944 ***P-59 Case History***.

6. Donald Lopez ***Fighter Pilot's Heaven: Flight Testing the Early Jets*** Washington, D.C.: Smithsonian Institute Press, 1995 p. 171.

7. "A Comparison of the Ground target Attacking Ability of the Jet Fighter vs Conventional Fighter" A Research Paper Submitted to the Faculty of the Air Command and Staff School of the Air University by Major James C. Lemmon, USAF, Maxwell AFB, Alabama, November 1948; "An Evaluation of Jet Fighter Aircraft for Tactical Air Operations" A Research Paper Submitted to the Deputy for Plans Headquarters Tactical Air Command by Lt. Colonel Richard Taylor, USAF, Langley AFB, Virginia, May 1949; "A Comparison of Jet and Conventional Fighters in the Conduct of Tactical Air Operations" A Research Paper Submitted to the Commandant of the Air Command and Staff School of the Air University by Lt. Colonel William P. McBride, USAF, Maxwell AFB, Alabama, October 1948; "A Comparison of Jet and Conventional Fighters in the Conduct of Air Operations" A Research Paper Submitted to the Faculty of the Air Command and Staff School of the Air University by Major Roland H. Leisy, USAF, Maxwell AFB, Alabama, December 1948; "Did the Air Force go Overboard on Jet Fighters?" A Research Paper submitted to the Faculty of the Air Command and Staff School of the Air University by Regular Course code No. 460, Maxwell AFB, Alabama, May 1949. All of the above taken from the microfilm collection in the Library of the Office of Air Force History, Bolling AFB, Washington, DC.

8. This fixation on the latest (even if not the most effective) technology has continued into recent times. In the late 1950s and early 1960s, the Air Force entirely abandoned gun armament on its fighter planes in favor of missiles - the "weapon of the future". Then in Vietnam it was found that the weapon of the future did not always work so well, and sometimes did not work at

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all, and that in combat it was desirable to have gun armament as well, so the Air Force began adding guns to its fighters again. Today, the technological fascination is stealth technology, which is supposed to make a plane invisible to radar. When properly applied, stealth can be a devastatingly effective technology, as was demonstrated in the Gulf War. It is, however, not perfect, nor is it useful or necessary in all situations. Yet the Air Force wants it on all sorts of planes - air superiority fighters, tactical ground attack aircraft, strategic bombers, and even helicopters. Mostly what stealth does is make an aircraft vastly more expensive, complex, and difficult to maintain. And because the extremely precise construction of the outer skin that makes stealth work at all degrades with even normal use, it also sharply limits the actual flying such a plane can do.

9. Walter Boyne ***Beyond the Wild Blue: A History of the U.S. Air Force, 1947-1997*** New York: St. Martin's Press, 1997, p. 26.

10. Conrad Crane ***American Airpower Strategy in Korea, 1950-1953*** Lawrence, KS: University Press of Kansas, 2000, p. 15.

11. Boyne, ***Beyond the Wild Blue*** p. 29.

12. The American Air Force fighter aircraft produced during 1940-45 include the following: Seversky P-35, Curtiss P-36 Hawk, Lockheed P-38 Lighting, Bell P-39 Airacobra, Curtiss P-40 Warhawk, Seversky XP-41, Curtiss XP-42, Republic P-43 Lancer, Republic P-44 Rocket, Curtiss XP-46, Republic P-47 Thunderbolt, Douglas XP-48, Lockheed XP-49, Grumman XP-50 Skyrocket, North American P-51 Mustang, Bell XP-52, Curtiss XP-53, Vultee XP-54 Swoose Goose, Curtiss XP-55 Ascender, Northrup XP-56 Black Bullet, Tucker XP-57, Lockheed XP-58 Chain Lightning, Bell XP-59, Bell P-59 Airacomet, Curtiss XP-60, Northrup P-61 Black Widow, Curtiss XP-62, Bell P-63 Kingcobra, North American XP-64, Grumman XP-65, Vultee P-66 Vanguard, McDonnell XP-67, Vultee XP-68 Tornado, Republic XP-69, Douglas P-70, Curtiss XP-71, Republic XP-72, Fisher XP-75 Eagle, Bell XP-77, Northrup XP-79B, Lockheed p-80 Shooting Star, Convair XP-81, North American P-82 Twin Mustang, and the Bell XP-83.

The American Air Force fighter aircraft produced during 1946-50 include the following: Lockheed F-80 Shooting Star, North American F-82 Twin Mustang, Republic F-84 Thunderjet, McDonnell, XF-85 Goblin, North American F-86 Sabre, Curtiss XF-87 Blackhawk, McDonnell XF-88 Voodoo, Northrup F-89 Scorpion, Lockheed XF-90, Republic XF-91 Thunderceptor, Convair XF-92A, North American YF-93, and Lockheed F-94 Starfire.

Note that these lists do not include the smaller but still substantial numbers of fighter aircraft produced and developed for the United States Navy during the same time period. Jones ***U.S. Fighters***, pp. 82-258.

13. Boyne ***Beyond the Wild Blue*** p. 23.

14. Allan R. Millet and Peter Maslowski ***For the Common Defense: a Military History of the United States of America*** New York: The Free Press, 1984, 1994, pp. 502-6.

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15. Crane ***American Airpower Strategy in Korea*** p. 16.

16. Memorandum for General LeMay, "Report of Fighter Requirements Committee" 25 July 1947, Box 38, Record Groupe 341, National Archives.

17. Staff Study "Penetration Fighter" 18 July 1949 Microfilm archive, Library of the Office of Air Force History, Bolling AFB, Washington, DC.

18. Jones ***U.S. Fighters*** pp. 235-7, 241-2.

19. Ibid., pp. 243-9.

20. Report "Military characteristics of Aircraft (All-Weather Fighter)" to Assistant Chief of Air Staff, 24 July 1947. Microfilm collection, Library of the Office of Air Force History, Bolling AFB, Washington, DC.

21. Jones ***U.S. Fighters*** pp. 232-4, 238-40, 253-8.

22. Ibid., pp. 222-4.

23. Richard B. Frank ***DOWNFALL: The End of the Imperial Japanese Empire*** New York: Random House, 1999, pp. 312-3.

24. D. Clayton James ***The Years of MacArthur: Volume III - Triumph and Disaster, 1945-64*** Boston: Houghton-Mifflin, 1985, p. 581.

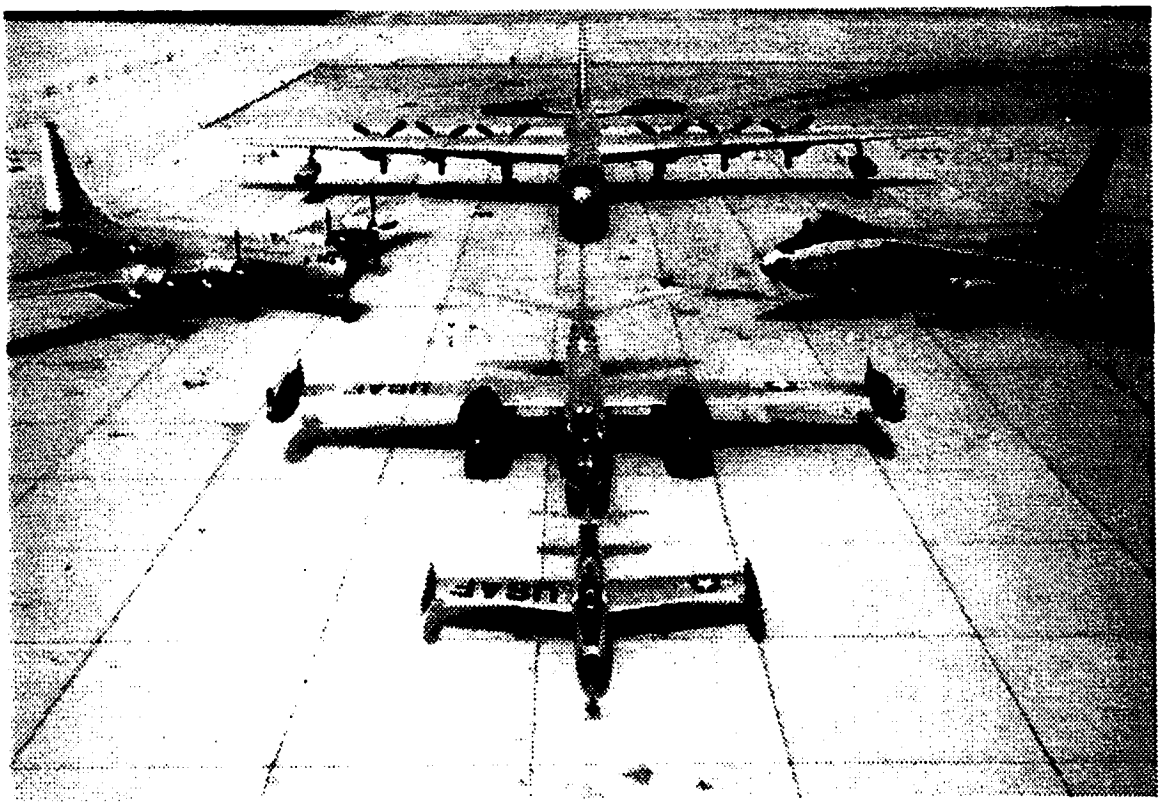
25. Boyne ***Beyond the Wild Blue*** p. 28.

26. Millet and Maslowski ***Common Defense*** pp. 498-501.

27. Ibid., p. 499.

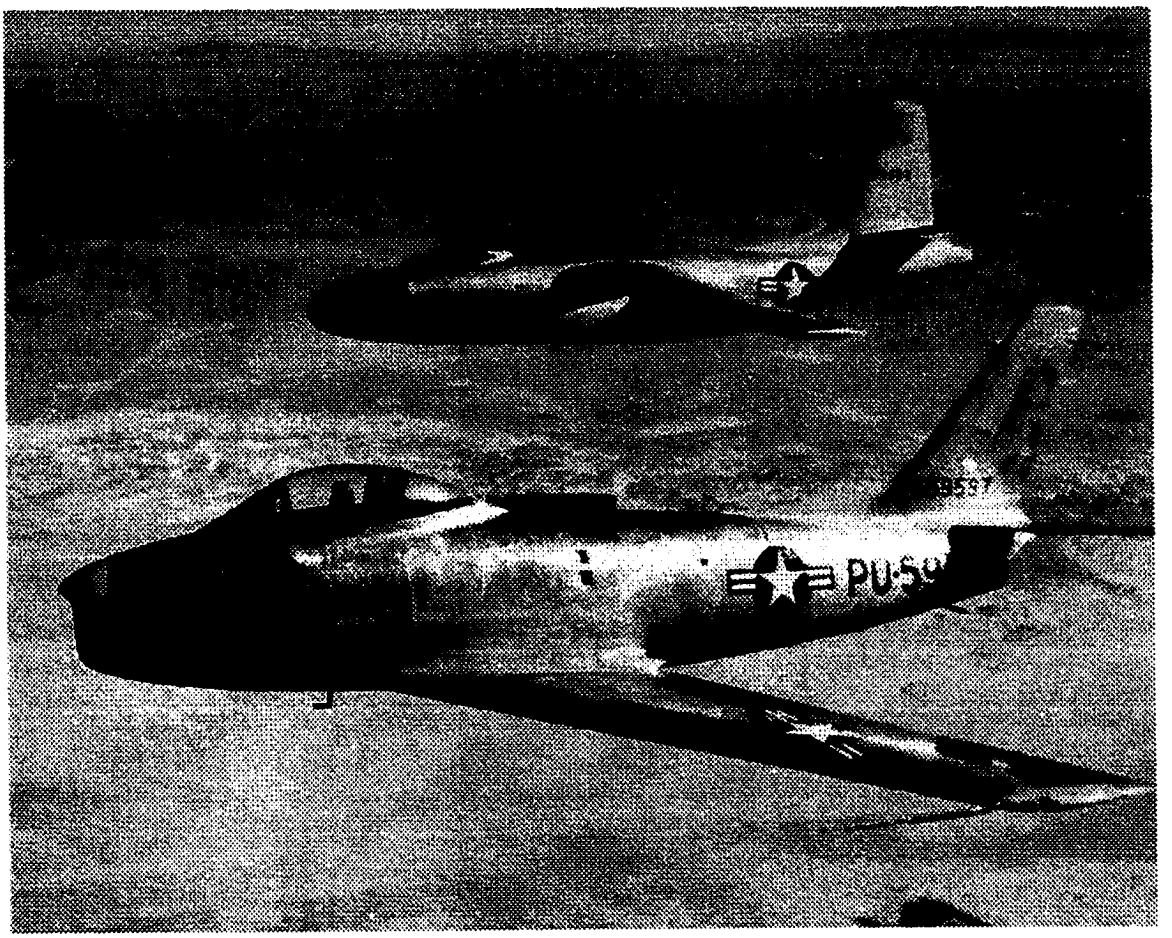
28. Dr. W. B. Shockley "Relative Technological Achievements in Weapons Characterisitics in USSR and USA" 30 January 1946. Microfilm Reel 186, Papers of General Henry H. Arnold, Library of Congress.

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A display of the nuclear capable aircraft of the United States Air Force, from the early Cold War. Beginning at the bottom, the planes are the F-84G Thunderjet, the first tactical aircraft capable of delivering a nuclear weapon. Directly behind it is the North American B-45 Tornado, a transitional machine which began development near the end of World War II. To the left of the B-45 is the Boeing B-50 Superfortress, a modified version of the World War II B-29, which served in Korea, and for several years, was the only aircraft the Air Force owned which was capable of carrying nuclear weapons. To the right of the B-45 is the Boeing B-47 Stratojet, the most modern of the aircraft in this photo. It not only incorporates jet engines but also a swept back wing, and was America's first purpose designed nuclear bomber. In the rear is the massive Convair B-36 Peacemaker. First envisioned as a transatlantic bomber in the event of England's elimination from the war, the B-36 eventually saw service as the first intercontinental bomber. The original design used the six massive turboprop engines driving the pusher propellers, and the production versions eventually added four regular jet engines under the wing tips, as seen here. Photo credited to Office of Public Information, dated 8 September 1953. (National Archives, Photographic Division, Box 2221, Number 21463)

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America's newest aerial weapons take to the skies. The North American prototype XP-86 Sabre fighter flies formation with a North American B-45 Tornado bomber. Photo credited to Office of Public Relations, dated 7 April 1948. (National Archives, Photographic Division, Box 2221, Number 21454)

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"The name Shooting Star fit the P-80 well. I felt as though I were riding on a shooting star, that all my training and flying up to now were to prepare me for this airplane. I felt as though I were, at least for the moment, king of the sky."
Fighter ace and test pilot Donald Lopez, describing his first flight in a P-80 Shooting Star. [1]

Chapter 7
Coming of Age: The P/F-80 Matures

As mentioned earlier, the end of the war produced a number of changes in the various American jet development programs, including the P-80. Drastically reduced budgets meant a much more careful allocation of resources, which in turn called for more planning and less breakneck speed in development. Likewise, the rash of P-80 accidents in the closing months of the war, especially the death of Major Bong, produced a greater emphasis on safety and training than simply getting the jets off the assembly line and into the air. The P-80 program adopted a more measured pace than before, and several years would pass before the P-80 could truly be said to have reached full, mature development.

One potentially confusing issue must be addressed at this point. As discussed in the previous chapter, the Air Force fought for and eventually won its independence from the Army during this period. Having done so, the Air Force proceeded to change some of its aircraft designations. Most remained unchanged, such as B-(bomber), O-(observation), C-(cargo), and A-(attack), but several types were changed completely. P-(pursuit) became F-(fighter) on 11 June 1948, and F-(fotographic) became RF- (reconnaissance fighter) at the same time.[2] This change was applied to all fighters, even those built prior to this date.

This meant that the designation for several of the aircraft in this study, primarily the P-80, P-84, and P-86, would change during the period under discussion. This change has the potential

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for confusion among readers not familiar with the situation. In books dealing with the aircraft of this period the standard technique for dealing with this change is simply to refer to any fighter prior to the date of the change by using the "P" designator, and after with the "F" designator.[3] This is admittedly awkward in some cases, as the designation of an aircraft could shift back and forth during a discussion if the plane was referred to at varying points in time. An alternate solution is to designate a single aircraft as the "turning point", and refer to all prior-built fighters as "P" and all subsequent-built ones as "F".[4] This solution is textually simpler, but leaves a single aircraft stuck with an awkward "P/F" designator. The most common aircraft to be used as this delineator is the P-80, as its operational development and career spanned both sides of the designation change. A third possibility would be to simply refer to all post-war fighters by using the "F" designation - historically inaccurate but the least confusing to a reader.

The solution adopted in this work will be the first, using the "P" designator for references to fighter aircraft prior to 11 June 1948, and the "F" designator after that date. Having discussed the issue of the changing designation of the P-80, the next task will be to present and discuss the various sub-designations of the P-80 to understand what is meant by them.

The earliest production models of the P-80, which were contracted for during the war, were referred to a P-80As. These machines were essentially the same as the YP-80A, including all the modifications made up to that point. The earliest P-80As did not have the boundary layer bleed ducts or the other fixes that arose out of testing the YP-80As, as it took time to integrate these changes into an assembly line process that had already begun when the need for such changes was understood. The first few examples of the P-80A were delivered during the war, but all of them were eventually returned to the factory for upgrades and fixes for various problems.

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The P-80A is also occasionally referred to in Air Force documents as the P-80A-1.[5]

General Electric, builders of the I-40 engine that powered the original P-80 prototypes (save for the original XP-80, *Lulu Belle*, which had been powered by the British-built Halford Goblin engine) eventually proved unable to keep up with demand for the engine, and so a contract was awarded to the Allison division of General Motors instead. Produced by Allison, the engine was redesignated the J33. Various improved versions of the engine would equip subsequent models of the P-80, with advancing numeric designations. Unfortunately, interchangability between the various models of the J33 engine was essentially non-existent, so in order to assure uniformity of performance and maintenance eventually all P-80s were upgraded to the latest model of engine.

The P-80A-1 was powered by either the J33-A-9 or J33-A-11 engines. The higher model numbers did not necessarily indicate greater power from the engine, but could mean changes made to improve reliability and ease of maintenance. Plans to incorporate improved versions of the J33 in the P-80A-1, or indeed to secure adequate supplies of the current engines, were frustrated by a strike at General Motors at the end of 1945 that paralyzed the company for months. This completely halted deliveries of all J33 engines to Lockheed for the duration of the strike and for some time thereafter. When added to the problems of late engine deliveries and serious and numerous engine defects, delivery of P-80A-1s remained seriously behind schedule for some time.[6]

Eventually, supplies of the new J33-A-17 engine became available. These were installed in P-80s beginning with the 346th production machine, on 24 April 1946. The new engine prompted a change in designation to the P-80A-5, which was otherwise similar to the A-1.[7]

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During a long-distance high speed test, several of the early P-80A-1s were modified to carry extra fuel tanks on the wingtips. This proved to be highly successful, and became a standard feature on all subsequent P-80s.[8] These wingtip mounts were also tested as attachment points for carrying bombs. So equipped, the P-80 was tested as a ground attack machine. "In other respects, the airplane was an ideal fighter-bomber, and all pilots assigned to the test had concurred in stating that the P-80 was the best fighter-bomber tested at this station from a standpoint of stability, visibility, and general handling characteristics during a dive bombing approach."[9] However, when carrying bombs in this configuration, the P-80 would be unable to carry extra fuel tanks, severely limiting its range.

The P-80N was to be the designation for P-80A-1 aircraft produced by North American. When the war in Europe ended and the government canceled the contract with North American, the P-80N designation was withdrawn from use.[10]

Once testing of the P-80 began, Lockheed compiled a list of changes and improvements it intended to make to the P-80. The Air Force was receptive to this idea, and in early 1945 they tentatively designated the P-80Z as the aircraft to incorporate all of these changes.[11] The "Z" designation was to indicate the maximum possible development of the type. Further testing of the P-80 as well as examination of the ideas in the study led to the conclusion that the "Z" concept as proposed was unworkable with the P-80, as the changes needed to incorporate them would result in what was an essentially totally new aircraft. Many of these advanced ideas eventually found their way into Lockheed's XF-90 design, created to compete for the Penetration fighter contract.[12]

The "Z"concept remained with the P-80 program, if in a more limited form. The "Z"

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designation came to refer to a whole laundry list of mostly minor improvements and changes to the basic P-80 design, over 65 of them in all.[13] By the time this came about, however, the Air Force's traditional designation system had reasserted itself, and these aircraft were instead given the designation P-80B-1. The final 240 aircraft of the original 917 authorized in Contract W33-038 were to incorporate these changes. This was made official by Change to Order 81, dated 2 April 1947.[14]

The most important of the changes between the P-80A-5 and the P-80B-1 were the installation of the J33-A-21 engine, which provided an additional 600 pounds of thrust, the addition of a water-alcohol injection system for the engine, the strengthening of the nose bulkheads and the installation of the new Browning M3 .50 caliber machine gun to replace the earlier M2 version of the same weapon, and the installation of an ejection seat for the cockpit.[15]

The use of a more powerful engine is an obvious advantage, but the water-alcohol injection system deserves additional explanation. This system was a modification of a water injection system that had been widely used among the various combatants during World War II in their piston-engined combat aircraft. This system provided aircraft with what might be called "emergency overdrive." The idea of adding water to a fuel burning engine to increase the power output might seem a little odd at first, but the physics of the idea are simple and sound.

In the piston-engined fighters, the water was injected directly into the cylinders. The water cooled the cylinder enough to allow higher combustion temperatures, and thus more power, without damage to the engine, at least for a short time. The system could temporarily produce as much as an extra two to four hundred horsepower, but could not be used for more than five minutes or so without permanently damaging the engine.[16] If used for much longer than that, the

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increased temperatures produced by the process could actually destroy an engine, causing it to fail in flight. But the extra power boost in combat could be invaluable if used properly.[17]

The same basic system was originally tested in the P-80, and generally worked well. However, at the high altitudes at which the P-80 operated, the water could freeze, so alcohol was added to prevent that from happening. It did, but this led to other complications. The P-80 used compressed air from the engine to operate certain instruments, pump fuel from the tip tanks and pressurize the cockpit. Initially the water injection system had a tendency to leak into the pressurized air, filling the instruments with water, adding water to the fuel in the tip tanks, and releasing a cloud of water vapor into the cockpit. If these problems weren't enough, when the alcohol was added to prevent the freezing, as Kelly Johnson put it: "the pilot problems increased because he now gets drunk as well as blind!"[18] Eventually the bugs were worked out of the system and it provided a reliable means to temporarily increase engine power.

The Browning M2 .50 caliber machine gun was one of the most effective aerial machine guns of the Second World War, and had been the standard armament for virtually every American fighter.[19] The M3 version was essentially the same gun, with an effective rate of fire increased from 900 rounds per minute to approximately 1,200 rounds per minute.[20] Delays in the delivery of the M3 gun required the initial installation of the earlier M2 version in the first B models of the P-80. The need to strengthen the bulkheads in the nose of the P-80 arose from the fact that the nose was where all six machine guns were located, concentrated in a tight cluster to increase the damage caused by a successful attack.

The problem with this arrangement was that the bulkheads that anchored and supported the machine guns had insufficient strength. Consequently, firing all six machine guns

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simultaneously seriously damaged the nose bulkheads. This could not only throw the machine guns out of alignment, making it impossible to hit a target, but also had the potential to disrupt the aerodynamics of the entire plane. As a result of this problem, P-80 pilots were prohibited from firing more than two of the machine guns at a time (fighters had selector switches that allowed pilots to fire fewer than the maximum number of guns the aircraft carried, usually in multiples of two weapons).[21]

The ejection seat was designed and included by Lockheed because of the difficulty of exiting the P-80 during flight. Since the introduction of pilot parachutes late in the First World War, combat aircrew have occasionally had to leave their plane while it was still flying. By World War II this maneuver had developed into a standard routine for fighter pilots. First, the canopy had to be not only opened but released or jettisoned, so as not to strike the pilot as he exited the plane. If possible, the plane would then be rolled onto its back, so that gravity would aid the pilot in escaping. Then he would unbuckle his safety straps and, with a little luck, fall free of the plane. He could then pull the cord to release the parachute and drift gently to earth.

This, then was the theory of "bailing out", and for the most part, it worked reasonably well. However, as the speed of fighters increased, this maneuver became increasingly difficult to execute. Higher speeds means greater wind resistance, which makes it difficult to both discard the canopy and to escape from the cockpit. In both cases the pilot would be required to push out against extremely strong air pressure. Piston engined fighters during World War II usually had to slow down considerably to ensure a reasonable chance of success of bailing out, and the new jets, with their much higher top speed, made it even more difficult for the pilot.

The Germans predictably had been among the first to recognize this need and attempt to

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fill it. During the war, two German piston engined fighters, the Dornier Do 335 and the Heinkel He 219, became two of the earliest (the other one being the Swedish Saab J21) production combat aircraft to be equipped with ejection seats. The concept of an ejection seat is simple enough, if a bit intimidating. The seat is placed on a track, not unlike that of a sliding window, and explosive charges are located beneath the seat. In the event that the pilot wishes to exit the airplane in flight, the canopy is jettisoned (by an explosive charge, in the case of the Do 335), and the charges under the seat are detonated. The explosion propels the seat out of the cockpit, and the pilot is able to parachute safely.

Of course, the early models still had a few bugs. During the testing of the Do 335, German pilots told of finding crashed Do 335s with the pilots still inside. The canopies had been jettisoned, but the seats remained in the cockpit, the pilots' bodies strapped firmly inside. The likely reason for that was that the pilots' bodies were missing their arms. To jettison the canopy of the Do 335, the pilot had to grab a pair of handles attached to the canopy frame and twist them to activate the explosive charges. If the pilot was gripping the handles too tightly when the charges went off, he was unable to release the canopy in time, and it could take his arms with it.[22]

The P-80, as first designed, had neither an automatic canopy jettison system nor an ejection seat. It is probable that a number of the fatalities among the early P-80 accidents were caused by the inability of the pilot to get out of an airplane in trouble. After a few near accidents where the pilot was unable to leave the plane but eventually regained control of it, the Air Force and Lockheed decided that some sort of automatic pilot exit was needed, and the first American ejection seat came into use. This seat was rather crude by today's standards, and several years were needed to make it fully operational and installed in all P-80s. Nevertheless, part of the pilot

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exit problem had finally been solved.[23] The other element, an explosive canopy remover, would be developed later by Lockheed as a kit and retrofitted to P-80s to complete the package.[24]

It was rather daunting at first for the pilots to sit on top of some fairly potent explosives, and many pilots left the safety arming pins in place, accepting that extra time pulling the pins would add to a bail out rather than risk the accidental detonation of the seat charges. But as time went by and no problems with the ejection mechanism were reported, pilots began to remove the safety pin before flight as they were supposed to do.[25]

The next P-80 was the P-80B-5. The B-5 was a B-1 that had been modified to operate in cold weather. This meant minor changes to the engine, lubricants, and starter. It also included the installation of a radio compass, a device which could lock on to a radio signal. The device would then indicate the compass bearing of the signal, allowing the pilot to guide his aircraft towards it even in conditions of poor visibility. The B-5s also finally received the new M3 version of the Browning machine guns. This new designation was first applied on 3 June 1947. As all P-80B-1s were intended to be winterized, this new designation would eventually come to apply to all P-80Bs.[26]

The next version of the P-80 was the P-80C. This would be the final production version of the P-80. The primary change in the P-80C was the installation of the J33-A-23 (later the J33-A-35) engine, which increased the normal maximum thrust available from 5,200 to 5,400 pounds. This engine also was equipped with the water alcohol injection system. Tests had been conducted with earlier models to determine the P-80's potential as a ground attack machine, but the earlier models of the plane could only carry bombs on the wingtip shackles. This meant that if the plane would carry bombs it could not carry external fuel tanks, severely limiting its combat range. The

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P-80C solved that dilemma by incorporating permanent weapons attachment points under the wings. Early in the P-80C's production run the designation change went into effect, and the P-80C became the F-80C.[27]

The second XP-80A had been modified to add an extra seat for an observer/flight engineer, and from that Lockheed had developed a plan to modify the P-80 to accept a second seat. This aircraft would fill the role of a jet trainer. But for several years the Air Force remained uninterested in the concept. Working with a limited budget, and with much of that budget going to SAC, the Air Force did not want to "waste" fighters as trainers. Not until 1948 would the Air Force contract for a limited number of what was then called the TF-80C. This plane would later be redesignated the T-33, known affectionately to its pilots as the "T-Bird." It would remain the Air Force's primary jet trainer for decades, far outlasting its fighter predecessor.[28]

In the closing stages of the Second World War, the Air Force had tried, almost frantically, to get the P-80A into squadron service and into combat. Although the war ended more abruptly than expected, the efforts to bring the P-80 into operational service continued to have a high priority. The Air Force's efforts were frustrated by production delays, previously undetected problems with the plane and the unexpected difficulty of transitioning pilots into the new plane. The introduction of a new combat aircraft always entails delays, problems and accidents, even (or especially) from exceptional planes. These difficulties stemmed from a variety of causes - the pilot's inexperience and/or unfamiliarity with the new machine and its performance and quirks, previously unknown problems with the plane coming to light, and the need to learn to use the aircraft not under the optimal and tightly controlled conditions of a test program, but during the rough and tumble of regular operational use.

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A prime example of such problems was the Martin B-26 Marauder, a World War II bomber. The B-26 was designed for high performance, not easy handling, and was generally greeted with suspicion and mistrust by the crews who first received it. Built in Maryland, it was known to crews as the Baltimore Whore, because its short wings gave it "no visible means of support." The primary training base for the aircraft was McDill field in Florida, and a number of crashes nearby gave rise to the saying among the crews "One a day in Tampa Bay." The machine's high performance coupled with inexperienced crews produced a high accident rate and the nickname "Widow Maker." Yet in the hands of experienced pilots the B-26 was just as safe as any other bomber, and Martin's decision to concentrate on performance was validated by the fact that the B-26 compiled the lowest loss rate for any Allied bomber in Europe. One B-26, named *Flak Bait*, survived more missions than any other Allied bomber - 202. Obviously, it was not just fighter planes that suffer from teething problems.[29]

At the same time the Air Force was finally introducing this radical new jet fighter plane, it was losing most of its experienced personnel. The abrupt demobilization following the war reduced many units to hollow shells. This loss was not just among the pilots, but perhaps even more importantly, among trained ground crew who were needed to maintain and repair the equipment.[30]

Although the Air Force lost the majority of its personnel, most of the fighter pilots that did remain in the service were combat veterans. This meant they were highly experienced pilots, seemingly ideal candidates to learn to fly a hot new fighter. However, it also meant that they were young, aggressive, and very, very cocky. During wartime, especially in combat zones, many of the normal flight safety regulations are relaxed or dispensed with. A tight formation

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take-off through heavy overcast would be insane and unthinkable during peacetime, but was sometimes necessary for combat missions. As a result, many of these young hotshots were inclined to consider rules and regulations to be optional, appropriate for mere mortals, perhaps, but unnecessary for highly skilled fighter jocks. This cavalier attitude would contribute significantly to many of the early jet accidents.

Another complication was that all the early jet fighters were single seat aircraft. This mean that any pilot who learned to fly jets made his very first jet flight "solo," as the pilot. He had no way to get used to the idiosyncracies of the plane as an observer, learning from a more experienced pilot. The very first P-80 pilots read the pilot's manual, took a written test, climbed aboard, and took off. Later pilots were trained in "captive" P-80s - that is, ones that were secured in stands on the ground.[31] Although these allowed the pilot to gain familiarity with the controls of the aircraft, he certainly had no exposure to its flying characteristics. These were hardly the optimal ways to introduce a pilot to a new airplane, especially one as different as the P-80. Not until the introduction of the TF-80C (later the T-33) would the Air Force have a suitable two seat jet trainer. This "throw him in the deep end" approach to pilot training undoubtedly contributed to a number of early P-80 accidents.

In the case of the P-80, the difficulties imposed by all of the above elements were exaggerated by a number of additional factors. The most obvious was the new powerplant. Although simpler to operate in many ways than a piston engine, jets have a number of important operational differences from them. These include the lack of torque, which is produced by the rotating propeller and pulls the aircraft to one side, (Pilots typically have to compensate for torque by using the rudder. If there is no torque, the pilot may overcompensate with the rudder), a

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significantly higher fuel consumption rate, especially at low altitude, an aerodynamically cleaner airframe due to the lack of a propeller, which made it easier to reach high speeds and thus the critical mach number with its potential for damage or disaster, and a much more gradual increase and decrease of power.

To this can be added the extreme sensitivity of the aileron controls. Kelly Johnson had introduced hydraulically assisted ailerons instead of the more common mechanical linkages, to aid in maneuvering the plane under the increased pressures of the extreme high speeds at which it was capable of operating. Although intended for assistance at high speeds, the boost, and thus the sensitivity of the controls, persisted at all speeds. Even Milo Burcham, Lockheed's chief test pilot and the first man to fly the XP-80, found the extreme sensitivity of the controls unnerving at first.[32] Certainly less skilled pilots may have over-reacted when they first encountered the trait. In a later aircraft, the P-84, this trait was corrected by adding variable boost to the aileron control. Variable boost allowed the pilot to add extra power to aileron control at high speeds, when it was needed, and little or no additional power at low speeds, when it was not necessary.[33]

As a result of these various factors, early P-80s had an extremely high accident rate when compared to the total number of hours the aircraft had flown. The various accidents of the wartime YP-80s and P-80As have already been noted. On 24 August 1945, the Air Force released a special accident report on the P-80. This report stated that "An analysis of P-80 accidents from Oct. 1944 through 8 Aug. 1945 revealed that there had been 15 P-80 accidents. Continental flying time for the P-80 had been very limited; from Nov. 1944 through July 1945, 522 hours were recorded. The accidents did not reveal a repetitive pattern of causes, but each indicated a weakness in the design or operation of the aircraft."[34]

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Largely as a result of these various accidents, the Air Force mandated an official Accelerated Service Test of the P-80 to determine if the airplane was intrinsically safe or dangerous. These tests consisted of five aircraft each accumulating 100 hours of flying time. The aircraft performed no acrobatic maneuvers in these tests, simply took off, flew straight and level, making broad and gentle turns, and then landed. Fuel consumption and performance at various altitudes was measured. The tests were completed between 3 October and 6 November 1945, without a single accident. To quote the report of the tests: "The test proved that the P-80A was safe for flight provided that satisfactory maintenance was performed. ....if proper and careful consideration was given to the recommendations included in this report, the maintenance troubles on the P-80A type aircraft would be greatly minimized."[35]

This test, unfortunately, did not end the abnormally high accident rate for the P-80; the trend would continue for at least another year. In a Special Accident Report dated 28 October 1946, the Air Force concluded that "The accident rate for the P-80 was more than twice that of any other fighter, excluding the P-59, which did very little flying."[36] David McLaren calculates that "Between the period August 9, 1945 and the end of March 1946 the accident rate stood at 1272 accidents per 100,000 flying hours, ...From the period April 1 through August 31, 1946, the average changed through an increase in flying time,...which resulted in a figure of 417 accidents per 100,000 hours."[37]

The Air Force, however, did not feel that the P-80 was solely, or even largely responsible for this high accident rate. The same Special Accident Report concludes that "The P-80 had a high rate not only because it was a new airplane and, consequently, had many mechanical 'bugs' but also because the pilots themselves were guilty of the same performances which were exhibited

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daily by inexperienced pilots."[38] The Report provides statistics on the accidents which seem to verify this. "Thirty-six P-80s were involved in accidents during the period from 1 Apr. through 31 Aug. 1946. Four of the pilots were killed, five received major injuries, and 27 were uninjured. Thirteen of the airplanes were wrecked, 19 suffered major damage, and 4 suffered minor damage. ....Nineteen accidents were caused by pilot error, 10 were caused by mechanical error, 4 were caused by a combination of the above two factors, 4 were caused by weather, supervisory error, or a similar cause."[39]

In most cases unfamiliarity with the new jet powerplant, coupled with reflexes conditioned by the responses of the big piston engines, seems to have contributed to the accidents. Although jet engines produced a great deal of power, they accelerated and decelerated very slowly compared to piston engines. This meant, for example, that if a pilot got into a landing pattern, then decided to abort the landing and go around again, he might lack the power to do so, especially if he was close to landing speed or if he tried to climb away too steeply. A maneuver that was fairly routine in a big piston-engined fighter could be suicidal in an early jet fighter. The cure for these accidents was not only to fix the bugs and give the pilots more jet training, but to tighten standards for maintenance, flight planning, safety, and pre-flight checks. As these fixes were put in place, the accident rate for the P-80 dropped to a level equivalent to other fighters, and it proved to be a reliable and durable aircraft.

Based on the high accident rate for the relatively low number of hours flown in the P-80, it might be thought that it would have been an unpopular aircraft among the pilots. In fact, the reverse was the case. Pilots reported almost universal appreciation for the P-80, both on first impression and after considerable experience with the plane. Some of that positive attitude may

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have come from the novelty of a jet fighter and the high speed it was capable of, but most of it seems to have stemmed directly from the performance and handling of the aircraft itself. Aside from the highly sensitive aileron controls, a somewhat cramped cockpit, and the difficulty exiting the aircraft in flight (a problem that affected relatively few pilots), P-80 pilots were effusive in their praise of the aircraft. The feelings expressed by test pilot and fighter ace Captain Donald Lopez after his first flight in a P-80 are typical:

> The P-80 was a delight to fly. All the controls and instruments were where they belonged, and the control pressures were well balanced. The elevator trim button on top of the stick was a great innovation. All the elevator trimming could be done without taking my hand off the stick. ...The elevator trim switch was most appreciated when the dive brakes were operated, especially at high speed.
>
> ...After a few rolls and loops, I headed back to the field for landing. As I had been told, the P-80, even with everything down for landing, did not decelerate like a prop plane with the power off, because the propeller acts as a brake at idle power. Consequently, the approach had to be much flatter; with a steep approach, the pilot couldn't slow it down for landing within a reasonable distance. It was quite easy to land, and I taxied to the ramp with the comforting feeling that I was now a real jet pilot, notwithstanding my previous flights in the P-59.
>
> My feelings during that first P-80 flight are difficult to describe but even more difficult to forget. The name "Shooting Star" fit the P-80 well. I felt as though I were riding on a shooting star, that all my training and flying up to now were to prepare me for this airplane. I felt as though I were, at least for the moment, king of the sky. Later I made the transition to newer and faster jets, but none of my later first flights matched my first P-80 flight for pure exhilaration and joy.[40]

Likewise, Colonel William Councill had this to say about the sensations of flying a P-80 during his attempt to break a transcontinental speed record:

> The flight as far as Kansas was very much routine for all of us. We leveled out at 35,000 feet, using oxygen to supplement our

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> pressurized cockpits. We wore the regular leather summer flying jackets and were plenty warm. It is hard to convince yourself that you are flying the fastest plane of the Army Air Forces. The forward motion seems too effortless to maintain flying speed. The clatter of a trainer at 100 miles an hour gives a greater sensation of speed than the quiet cockpit of the Shooting Star traveling almost six times as fast. Unless you keep your eye on the gauges all the time and believe your indicated air speed, that plane will fool you every time.
>
> There was no roar of a giant engine -- only a quiet swishing sound that reminded me of coasting downhill in a free-wheeling Packard. The super General Electric turbojet was developing up to 4,000 pounds of thrust just behind my back, but I could hardly hear it. I was at sustained cruising speed nearly all the way to save on fuel consumption. There was no vibration at all. I felt smooth, surging power whenever I advanced the single throttle lever slightly. But there was never the quick acceleration that snaps your head back with its forward thrust.[41]

Despite occasional quirks and its early reputation for accidents, the P-80 proved to be a very popular plane among pilots, and was generally greeted with enthusiasm when introduced to units.

Although the various models discussed previously were the production versions of the P-80, the aircraft was also used as a platform to conduct a large number of tests and experiments. Some of these tests involved modification of the airframe, others involved adding components to the aircraft, and still others simply used the airplane in new and unusual ways. A brief summary of those experimental aircraft follows.

The most successful of the modified airframe experiments has already been mentioned - the two seat "stretched" version which became the TF-80 and then the T-33. Another modification of the airplane would also become quite successful, if not as long lived as the T-33. One of the original thirteen YP-80As had been modified by removing the machine guns from the nose and replacing them with high-speed cameras. The resulting unarmed reconnaissance plane

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was judged successful in tests, and entered production, first as the F-14, then the FP-80, and was eventually redesignated the RF-80. Early versions of the reconnaissance version of the P-80 had their cameras pointing straight downwards only, while later versions can be identified by the addition of small windows on the lower sides of the nose as well, allowing for side-oblique angle photography as well. The photographic versions of the P-80 were quite successful, equipping a number of squadrons and serving with distinction during the Korean conflict. Their high speed and stability made them excellent photographic platforms, especially for low altitude, but their high rate of fuel consumption did mean that the pilots had to be very disciplined and precise about navigation and fuel status.[42]

Another successful modification of the basic P-80 was the P-80R. The P-80R, nicknamed *Racey*, was a unique aircraft and never intended for mass production. The original airframe, 44-85200, was a P-80A that was modified to become the first P-80B. It was then modified again to become the P-80R. The P-80R was designed for one purpose only - to try to break the world level airspeed record. Modifications to *Racey* included smoothing out the skin and covering weapons ports, sharpening the wing leading edges, adding a smaller, low-drag canopy, and specially modified air intake ducts, also to reduce drag. The original redesign of the intake ducts, an attempt to make them completely flush with the fuselage, proved unsuccessful, and a slightly raised version was used instead. All of these modifications proved successful in increasing the speed that could be squeezed out of the P-80 airframe, and the plane participated in attempts to set a new speed record.[43]

Another P-80A, 44-85044 was modified to test the concept of prone piloting. The idea of placing a pilot in the prone position to increase his G tolerance was utilized in several previous

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aircraft, including the German Henschel Hs 132 dive bomber and Jack Northrup's XP-79 flying wing, but none of these aircraft had been flown enough to adequately test the concept. This P-80 had the nose armament removed and a prone piloting position installed. This position included a small bubble canopy on the nose, and two trays that supported the pilot's arms and contained basic flight controls. The regular cockpit was retained, as the prone position lacked navigation instruments and was incapable of taking off or landing.

This concept was tested extensively, and found that it did in fact dramatically increase the pilot's G tolerance, to over 8 G's (a normally seated pilot could only tolerate 5 G's before blacking out). In fact, the prone pilot had to be cautious in his maneuvers to avoid injuring the other pilot in the conventional cockpit with the high G forces. There were, however, a number of obstacles to widespread utilization of the concept. These included limited range of movement for the prone pilot's arms, complete inability to turn his head to the rear, the possibility of neck damage during high G manuvers from the position the pilot was required to hold his head in, and the fact that the standard back mounted parachute had the potential to break his back during the manuvers. So while the idea was workable, the difficulty in implementing it led to an abandonment of the idea. G tolerance research would instead eventually lead to partially reclined pilot's seats and high tech G-suits to combat the pressure.[44]

The other modifications of the basic P-80 involved tests of alternate armament arrangements. These tests were conducted with the same aircraft, 44-85044, that had done the testing of the prone pilot conversion. Various armament packages were tested in this P-80, with varying degrees of success, although none of them were adopted for use in the P-80. The first armament package tested was based on a system used by the Germans on their night fighters

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during the Second World War. Called *SchrageMusik* (literally - slanted music, ie; jazz) this system consisted of one or more 20mm cannon placed in a near vertical orientation on the night fighter, usually behind the cockpit. The night fighter would then position itself behind and below a British bomber (which possessed no downward firing guns) and blast it from the sky without the bomber even being aware of the threat.

The American system tested on the P-80 was more complex. It consisted of four .50 caliber machine guns on a swiveling platform. The guns could be rotated to a near vertical orientation and fired at a bomber overhead. The mount worked as intended, but when the guns were fired, the recoil drove the nose of the plane downward, preventing accurate fire. This system was abandoned as impractical.[45]

Next, 44-85044 was given a battery of four forward firing 20 mm cannon. Because of the size of the cannon, their breech mechanisms and ammunition supplies, they could not simply be placed in the same location as the standard .50 caliber machine guns. The cannon were also longer than the machine guns, and stuck out of the nose. The protruding cannon barrels were enclosed in rounded housings, giving the plane a very lumpy, sinister look. In this case the weapons worked fine, but were too heavy. While they were within the total weight carrying capacity of the P-80, their location in the extreme front of the nose seriously overloaded the plane's center of gravity. This threw the plane out of balance, with resultant control problems. This program, too, was abandoned.[46]

The final weapons system tested on this aircraft was a special rocket launcher. Again mounted in the nose weapons bay, this system fired six 5" FFAR (Folding Fin Aerial Rockets). This was a standard Air Force weapon, and had been fired from underwing racks against ground

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targets by most American fighters of World War II. As used on the P-80 it was intended to be used as an air-to-air weapon against bombers. The rockets were fired one at a time through a large tube that stuck several feet out of the bottom of the nose section. Again the system worked as intended, but as the rockets were unguided and thus rather inaccurate, and the plane could only carry six of them, it was decided that the system would be ineffective.[47]

Other test modifications of the P-80 were centered more around attaching things to the outside of the aircraft. The original attempt to attach extraneous equipment to the outside of the P-80 came in 1946. This was the attempt to break the transcontinental speed record. To aid in accomplishing this, external fuel tanks from another Lockheed product, the P-38 Lightning, were modified and hung from the wing tips of the aircraft. This project was an unqualified success. Not only did these tanks provide extra fuel, but they actually increased stability and made the ailerons more effective. Some pilots, in fact, preferred to leave the tanks on, even after they were empty rather than drop them, because of the beneficial effect they had on the plane's manuvers. Wingtip fuel tanks became standard, not only on the P-80, but on many subsequent jet fighter designs.[48]

Another wingtip attachment tested on the P-80 was a German wartime invention, the ramjet. The ramjet is extremely simple in concept, and in theory, could provide a great deal of additional speed for an aircraft equipped with one. A ramjet utilizes the same basic concept as the gas turbine engine, that of using compressed air and vaporized fuel to create hot exhaust gases and use the resulting reactive forces for propulsion. A regular jet engine creates the compressed air it needs to function by using one or more powered air compressors. These compressors add weight and power requirements to the engine itself.

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A ramjet, on the other hand, uses the principles of physics to compress the air for it. It is little more than an open tube narrowing to a combustion chamber, where the fuel and ignition is added. As the plane travels, air is forced down the open tube and compressed by the narrowing diameter. When it reaches the combustion chamber, it is sufficiently compressed to produce a great deal of thrust.

Ramjets had two major disadvantages. The first was an enormous fuel consumption rate, far higher than even the early jet engines. The second, and much more serious, was that since they require a moving airstream to function, they cannot be used on the ground or at low speeds. They were viewed primarily as supplemental power for higher speed, rather than a primary power source.[49]

Two P-80s were used to test ramjets. One, 44-85042, went to Wright Field, where tests were being conducted on captured German ramjets, originally using a P-51D. The P-51 was destroyed when one of the engines exploded during flight, forcing the pilot to bail out. The P-80 was intended to continue the tests, but there were concerns over what would happen to the aircraft if one of the two wingtip mounted ramjets quit in flight. Engineers thought that the sudden asymmetrical thrust could destroy the P-80, so few test flights were flown. Even the few flights conducted were difficult and disappointing.

Optimal altitude for operating the ramjets was 20,000 feet. But since the ramjets were running off the P-80's internal fuel supply, fuel was consumed very rapidly. This meant that the pilot would take off, climb to 20,000 feet, ignite the ramjets and hope he reached top speed before he was forced to shut them down and return to land the plane. On the last of these flights, the P-80 was severely damaged on landing.[50]

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The other P-80, 44-85412, went to Muroc to make the same basic tests, only using American-built examples of the ramjets. The same problems with fuel consumption were encountered during these tests. They were partially solved by attaching additional fuel tanks under the wings. It was concluded that the increase in speed was far outweighed by the enormously increased fuel consumption, and the project was ended.[51]

Another speed enhancement device was tested on the P-80, this one with more limited goals and much greater success. Like much of America's immediate post-war science, this, too came from German wartime work. During the war, the Germans found that some of their new jet aircraft, especially the largest and heaviest of them, the Ar 234, had difficulty taking off. Low powered engines and a heavy payload prompted a search for some way to assist the take off. The answer came from another scientific field in which the Germans also excelled, rocketry.

The Germans attached two small Walter liquid fuel rockets beneath the wings of the Ar 234. These rockets would be ignited when the aircraft was taking off, and the extra thrust they provided for the few seconds it took to exhaust their fuel was of great assistance to the plane. Once the aircraft had taken off, the rockets were dropped. Deploying their own parachutes, the rockets would drift back to earth, where they were collected and refueled for further use.[52]

After the war, Lockheed proposed the concept in a letter of intent to the Air Force. The Air Force agreed, and the rockets were built by Aerojet Engineering. The primary difference between the German and American rockets was that the American rockets were solid fuel disposable units, rather than the liquid fuel reusable ones the Germans had used. The program originally tested a single 2,000 pound rocket, but later decided to use two 1,000 pound rockets. They were mounted on the lower rear fuselage, just behind the wing, and activated by a switch on

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the pilot's control stick.[53]

Known by the somewhat inaccurate designation of JATO (Jet Assisted Take Off), or occasionally by the more accurate RATO, these devices proved to be entirely successful. They shortened the take-off run of a fully loaded P-80 from 4,000 feet to 2,500 feet, and reduced the distance needed to clear a fifty foot tall obstacle after take-off from 5,150 feet to 3,450 feet. Used primarily for training and air show demonstrations initially, they would eventually become standard equipment on F-80Cs and other jet fighters operating in a ground attack role in Korea.[54]

The final attachment tests to the P-80 were fairly standard ones for fighter planes. These were tests to hang air to ground weapons, such as bombs and rockets, on the P-80. The initial tests with bombs were successful, but since the bombs were hung from the wingtip shackles, any P-80 carrying bombs would have been unable to carry extra fuel tanks. So tests were conducted to see if bombs or rockets could be hung beneath the wings.

Initial tests were conducted with retractable mounting points, intended to hold rockets. There were two launch racks, or stubs, as they were known, under each wing. Each stub was intended to carry two rockets, stacked one on top of the other. The bottom rocket was supposed to fire first, and then the top one. Occasionally the bottom rocket failed to fire, and then the top one did. This was disconcerting to the pilot, to say the least. The stubs were designed to retract into the wing after the rockets had been launched to lessen the drag on the plane. Although they worked reasonably well for launching the rockets, the stubs were too short. The rockets were carried too close to the wings, and this disrupted the airflow over the wings, causing stability problems.[55] Lengthening the stubs would solve that problem, but make them too long to retract into the wings. This problem of the exact size of the external ordinance racks was a common one

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to many fighters, and often a bit of tinkering was required to find the optimal length. Eventually the permanent installation of underwing bomb and rocket racks would transform the F-80C into one of the key ground attack aircraft of the Korean War.

The P-80 was also used in some unorthodox roles, with varying degrees of success. The first of these new roles for the P-80 was that of carrier aircraft. Two of the early P-80As were given to the Navy for testing. One was a basic P-80, simply used by the Navy for flight tests. The other was modified at the Air Force's request to allow it to be catapulted off of and land on aircraft carriers.[56] Although demonstrating some good ship-borne characteristics, the P-80 was ultimately judged unsatisfactory for carrier operations, due to insufficient power available for a "wave off" (a request to go around and try the landing again) and a tendency to bounce when landing, which would cause the arrestor hook at the rear of the plane to miss the arrestor wires, with potentially disastrous results.[57]

Having completed these tests on a P-80A, when the Air Force asked Lockheed to modify a B model for similar tests, Lockheed balked. The tests had already been performed, the plane was not usable on a carrier, and the B model was not different enough from the A to warrant doing the tests again. The Air Force was persistent, but so was Lockheed, and eventually the request for the carrier modified B model was dropped.[58]

A P-80 was also used in a test to extend the range of the aircraft with the intent of providing fighter protection for bombers on long distance missions. This was a modified version of the Parasite fighter concept, only using a full-sized airplane. Instead of keeping the Parasite inside the bomber, it was thought that perhaps a large bomber could tow behind it a full sized fighter, with the engine off. When needed, the engine could be started, the fighter released, and

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the enemy dealt with. The fighter could then reattach to the bomber for the trip home. At least, that was the theory. The reality proved to be somewhat different, as Donald McLaren describes:

> On September 23, 1947 Lt. Colonel Pat Fleming, Chief of Fighter Test, took off to join up with the B-29 at 15,000 feet. It took several attempts to make the connection, for as Fleming got in too close under the B-29, the bow wave from the P-80 forced the tail of the B-29 upwards. Then attempting to attach the ring at the limit of the cable's extension, the cable was dancing around in the B-29's slipstream. Finally the link-up was made, and the P-80's engine was stopcocked for ten minutes while the P-80 was towed around.
>
> When Fleming attempted to release the hook, it would not open. He made several attempts at getting it open to no avail, and then the P-80 slid under the B-29 and the turbulent airstream overstressed the attachment point on the P-80 and Fleming was free. He was now faced with the hook's sheet metal installation folded back over the nose of his fighter and having to land without any forward visibility. (The B-29 was flailed by the cable until it beat a hole in the fuselage and imbedded itself, where upon Sgt.'s Clayton Burn and Fred Corbi, the scanners, wired it safely in place and the B-29 could make its own landing.) The program was terminated at this time....[59]

The most successful of the P-80's alternate roles was also its least glamourous. This was the role of a radio controlled drone aircraft. Lockheed initially proposed on 3 May 1945 to modify a P-80 for remote radio control for use as a dive bombing aircraft. This was a logical proposal, as a pilotless plane could pull significantly higher G loads than one with a vulnerable human pilot. The Air Force approved the project, and asked Bell Aircraft to undertake it, as they had done similar work on their own P-59.[60]

Bell modified two P-80As, 44-85407 and 44-85408. One was to be the radio controlled drone and the other the controlling "mother" ship. Due to primitive control equipment, the maneuvers possible for the drone ship were quite limited at first - simple banks only, and only

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within 10 miles of the control ship or a ground station. Obviously, dive bombing was not possible, given the limited maneuvers possible. The control ship used cutting edge television technology to monitor the drone ship during the tests.[61]

Eventually, as remote control technology became more sophisticated and capable, the remote drone program gained importance. A great many F-80s at the end of their service life ended up as radio controlled drones. F-80s modified as drones became known as QF-80s, and the entire program became known as Project Bad Boy. T-33 two seat trainers were modified as control ships. Both the sophistication of the maneuvers possible and the distance allowable between the drone and control ship increased greatly, and eventually drones were capable of fairly complex operations. Although never serving as dive bombers, drones did make a significant contribution to the Air Force.[62]

One of the most important role for the drones was assistance during nuclear weapons testing. In the early days of the atomic age, nuclear weapons were still detonated above ground in the deserts of the Southwest, and scientists wanted to take measurements, including aerial ones, in the area of detonation immediately afterward. The Air Force did not relish the idea of sending a highly skilled and expensive pilot through ground zero, so the QF-80 drones were used instead. Open ended instrument pods were hung on the wingtip shackles, and the drones were remotely guided through ground zero shortly after the explosion.[63]

The other primary use for QF-80 drones was as airborne targets for newer, more sophisticated fighters. Live firing remains the best way to teach combat skills, and a great many QF-80 drones were blasted from the sky to help a new generation of Air Force pilots acquire those skills.[64]

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Although the P-80A-1 was being produced in early 1945, getting the plane into service with actual combat units proved to be a fairly difficult process. Developmental problems with the plane combined with post war demobilization and budget cuts to slow active deployment of the aircraft. The first group to be equipped with the P-80 was the 412th Fighter Group. This was the group that had been originally formed to put the P-59 into operation. When the P-59 proved to be impractical as a combat aircraft, the 412th was shifted to the P-80 instead. The 412th was, after all, where all the non-test pilots in the Air Force with jet experience were.

Although some of the initial batch of production P-80s were in fact assigned to the 412th, problems with the plane led to all of these planes being returned to Lockheed for repairs and changes. When the war ended, America's first jet fighter group was in fact equipped with P-51 Mustangs, against the possibility it would be deployed to the Pacific before the P-80s were ready. Not until December of 1945 would the first more or less reliable P-80s reach the group. Within a few months, more planes had arrived, but the group was far from full strength when it was asked to perform a public relations mission known as Operation Comet.

Operation Comet was intended to show off to the country and the world America's newest and most modern fighter. The 412th was based at Palmdale Army Air Field in California. For Operation Comet it was to take a large number of planes, about a full squadron's worth, across the country, stopping at various air bases and flying demonstrations of the new jet fighter. (Typically there are 3 squadrons in a fighter group, about 25 to 30 aircraft per squadron.). This operation took place in May 1946. As an indication of the incompleteness of the group's transition to jets, the group was able to manage the mission by cannibalizing all of its other planes for spare parts to enable the 25 that went on the tour to function.

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From the Air Force's point of view, Operation Comet was a success, although it nearly turned into a fiasco. The trip from California to the East Coast was without incident, and generated a great deal of publicity. The stay at Washington's Andrews Field, in particular, was popular with the public. On the return trip, however, during a flight from Illinois to Oklahoma, severe weather caused several of the pilots to become lost, as the early P-80s were instrumented for VFR (Visual Flight Rules) only. Several minor to serious accidents were the result. No one was injured, however, and the Air Force was able keep mention of this potentially embarrassing incident from the public.[65]

On 3 July 1946 the 412th Fighter Group was officially deactivated, and then immediately reformed as the 1st Fighter Group. The squadrons composing the group were all redesignated, as well. The 31st Fighter Squadron became the 27th Fighter Squadron, the 445th Fighter Squadron became the 71st Fighter Squadron, and the 29th Fighter Squadron became the 94th Fighter Squadron. The 94th had a proud history in the Air Force, being the "Hat in the Ring" squadron that had seen service in the First World War.[66]

By the winter of 1946-47, the 1st FG was finally fully equipped and trained on their aircraft. So of course, when the Air Force's first jet fighter group finally became fully operational, it was RIF'ed (Reduction in Force). The 71st Squadron, for example, lost 75% of its officers, leaving it with exactly six pilots. The entire group would have to be rebuilt with essentially new personnel.[67]

While still coping with the loss of most of its personnel, the 1st FG participated in the "All American Maneuvers" held in Miami, Florida. These maneuvers were the first actual attempts at tactical maneuvers by jet fighters of a combat unit, and included demonstrations of formation

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flying and interceptions on B-29 bombers.

On 24 June 1947, the 1st FG was reequipped with P-80B-1s. Their A-5 aircraft were transferred to two other fighter groups, the 56th and 4th, that were transitioning to jets. On 7 August 1947, the 94th Fighter Squadron was ordered to Ladd Field, Alaska. They would be given the new P-80B-5 winterized fighters, and would be responsible for testing the aircraft in Arctic conditions. On 15 August 1947, the 1st Fighter Group was expanded and became the 1st Fighter Wing. On 1 December 1948, all F-80 groups and wings were transferred to Air Defense Command, to be assigned as interceptors. Finally, in February of 1949, the 1st FW received the brand new F-86A Sabre fighter, and gave their F-80Cs to the Air National Guard.[68]

The next two groups to receive the P-80 were both veteran World War II fighter groups. Both the 4th FG and 56th FG had served in the 8th Air Force in England during the war, the 4th FG flying P-51 Mustangs and the 56th FG flying P-47 Thunderbolts, and had been intense rivals competing for the highest score of enemy planes destroyed. When the war ended, the 4th had narrowly edged out the 56th in total score, 1,016 to 1,006.5.[69] These scores made the two groups not only the highest scoring in the 8th Air Force, but in all the U.S. Army Air Forces. However, the 8th Air Force, alone of all U.S. Air Forces, allowed pilots to claim as kills enemy aircraft destroyed on the ground. Eventually this practice was disallowed, and the scores of the groups were retroactively adjusted down to include only aerial kills.

Both groups had been temporarily deactivated after the war, but were reactivated a short time later, equipped with propeller fighters. The 56th FG was reactivated on 1 May 1946, and equipped with P-51H Mustangs, and designated as a VLR (Very Long Range) bomber escort group. The 56th FG received its first P-80As in March 1947, taking the 1st FG's old machines.[70]

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The 56th FG became the first American fighter group to deploy jets in strength to Europe, during the Berlin Blockade and Airlift Crisis in the summer of 1948. U.S. military presence in Europe was minimal at that time, and the 56th FG's commanding officer, Colonel David Schilling, a famous and high scoring (23 aerial victories) ace pilot from the war, volunteered his group to conduct a "show of force" mission. Although another F-80 group, the 36th FG, based at the time in the Canal Zone in Panama, was scheduled for redeployment to Europe, this would not take place for several months, and so Colonel Schilling's idea was readily accepted by the Air Force.

Beginning on 12 July 1948, this mission became known as Fox Able (Fighters across the Atlantic, using the military's phonetic alphabet). It was the first of several such missions undertaken by American jet fighters during the late 40s and early 50s. This first was not a permanent redeployment, but rather a "show the flag" type of mission. Colonel Schilling led sixteen of his fighters across the Atlantic in short stages, from the East Coast to Labrador, Greenland, Iceland, Scotland, England, and ultimately Furstenfeldbruck, Germany. While en route they encountered several British RAF Vampires flying the same route in reverse on a public relations mission to the United States. Once in Germany they provided escort for B-29s flying "show of force" training missions and also toured other U.S. bases in Germany. After several weeks they returned to America following the same route, where they again encountered the British Vampires. In April 1950, the 56th FG converted to F-86As.[71]

The 4th FG was reactivated on 9 September 1946, and fleshed out with some personnel from the 56th FG, an action that caused some mixed emotions between the two rival groups. Like the 56th FG, the 4th FG was given piston-engined fighters initially, a mix of P-47s, P-51Ds and P-51Hs. It received P-80s at the same time as the 56th FG, in March 1947. On 15 August

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1947, the 4th FG became the 4th Fighter Wing.[72]

The final stateside group to receive the P-80 was the 81st FG. Initially equipped with P-47Ns, they converted to the F-80C on 21 May 1949. They did not keep the Shooting Star very long, converting to the F-86A in December 1949. As the various regular Air Force groups converted to the F-86, their F-80s were generally given to Air Training Command or the Air National Guard.[73]

A number of other fighter groups stationed overseas received the P-80. The 36th FG received the P-80, and then was sent to the Panama Canal Zone. It is hard to understand the reasoning behind this move, as there was no conceivable aerial threat to the canal from anywhere in the region that warranted stationing America's best jet fighter there. In addition, the short range and limited navigation capabilities of the P-80 meant that it would not have been very effective operating from the Canal Zone. They did not remain there very long, for during the Berlin Airlift, in the summer of 1948, they were redeployed to Germany, which became their permanent station. They remained the only F-80 group in Europe. During the Korean War, individual squadrons of RF-80s were also sent to Germany, to help keep an eye on the Russians.[74]

All of the other P-80 groups were stationed in the Pacific. One, the 18th FG, was designated to receive the P-80 while the Second World War was still going on. Since the 412th FG ended up spending so much time training and working the bugs out of the P-80, the 81st FG would have been the first P-80 equipped group in a combat theater had the war not ended with the atomic bombs. But since the 81st FG was stationed on Luzon, in the northern Philippines, quite a long distance from Japan, the decision to give it the short-ranged P-80, and then keep it there, made about as much sense as sending the airplane to Panama.

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The 81st FG received its first few P-80As in March 1946. However, as no one in the group actually had any experience flying jets, they couldn't use them. Eventually, a number of pilots in the group did receive jet training, but keeping the P-80s flying proved to be a nightmare. They were a long way from the United States, and worse, in a relatively primitive environment, not an ideal situation when trying to use a new, quirky and maintenance-intensive aircraft. The situation was so impractical that eventually the group returned its P-80s and got additional propeller fighters. Then, beginning 9 November 1949, the group began to receive the newer F-80C. In January 1950, the group was redesignated the 81st Fighter Bomber Group. When the Korean War began, elements of the 81st FBW were dispatched to Japan. Eventually most of the newly designated 81st Fighter Bomber Wing ended up in Japan or Korea, although some of their pilots flew their combat missions in F-51 Mustangs rather than F-80s.[75]

Three other fighter groups, all part of FEAF (Far East Air Force) stationed in East Asia also received F-80s. The 49th FG, stationed in Japan, received F-80s in July 1948. The 35th FG, also based in Japan, received F-80s in January 1950. Finally, the 51st FG, based on Okinawa, received their P-80s in February 1948. All three of these groups would participate in the Korean War from the earliest stages.[76]

Another first for the P-80 was the formation of special acrobatic flying teams, using the P-80 as their demonstration aircraft. Initially, there was no single Air Force acrobatic team. The now famous Thunderbirds did not come into existence until 1953. So any number of acrobatic teams existed in the various commands. Probably the best known of the early P-80 teams was the Acrojets. Formed in 1948, the Acrojets were not intended for public performances. At this time, just as the Air Force was acquiring its new jet fighters, it had lost almost all of its experienced

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pilots. Training and skills had suffered, and the Acrojets were formed to demonstrate that excellence and precision in flying was possible with the new jets. They flew no fancy stunts and maneuvers, just the basic formations and maneuvers expected of Air Force pilots. But they flew them with style, precision and panache. They toured Air Force bases, putting on shows for their personnel, and helped convince them that mastery of these complex new machines was possible.

Other precision Air Force acrobatic teams that used the P-80 at some point in the late 40s included the Skyblazers, Silver Sabres, Polarjets, Florida Rockets, and the Minutemen. Precision maneuvers in jet fighters were actually easier and capable of tighter intervals than in prop fighters. Lacking the torque, prop wash, and propeller clearance needs of piston engined fighters, jets were capable of exacting flight maneuvers. These teams paved the way for the later, more official teams.[77]

One additional area of the P-80's service during the post war period should be discussed. This is the their participation in setting several significant speed records. Although these records did not remain unbroken for great lengths of time, they did in many cases indicate the return of cutting edge performance to American aviation.

During the testing of the YP-80A in February 1945, it was proposed to use two of these prototypes to attempt to set a transcontinental speed record. The primary purpose of such a flight would be to test the range and cruising speed of the aircraft. This idea remained a proposal only, due to the necessity of using all the YP-80A prototypes for testing and special projects such as Extraversion. The idea was revived near the end of 1945, however, after enough safety tests had been performed on the aircraft to get them cleared for regular operations. Lockheed was responsive to the idea as well, and promised to assist in any way possible, modifying the needed

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aircraft and providing trained maintenance and service personnel.[78]

Three P-80As were used in this project. They would be flown by Colonel William Councill and Captain Martin Smith, both from the Flight Test Division at Wright Field, and Captain John Babel from the 412th FG. Colonel Councill would attempt a non-stop flight from Long Beach, California to La Guardia Airport in New York, while the two captains would make a single refueling stop at Topeka, Kansas while flying the same route. All transcontinental speed runs are made from west to east, to gain the benefit of prevailing winds.

All three P-80s were regular production machines, but were modified by having the nose armament removed and replaced by a 95 gallon fuel tank. All the planes were further modified to carry additional fuel tanks on their wing tips, the first P-80s to do so. Colonel Councill's machine would have a 310 gallon tank on each wing tip, while the two captains would have 165 gallon tanks on each wing. This gave Colonel Councill's machine a total fuel capacity of 1,150 gallons, and the other two machines 850 gallons. The primary concern with the external fuel tanks was to make sure they both fed evenly to the engine. If the fuel flow from the two tanks was uneven, then the different weights at the wingtips could have a crucial effect on the ability of the P-80 to fly safely.

Some modifications were made to the cockpits and radio installations of the three machines, and on 26 January 1946, the three machines took off from Long Beach Municipal Airport and headed east. The flight for all three was essentially uneventful, and all three planes benefitted from a strong tail wind. Colonel Councill completed his 2,453 mile trip in 4 hours, 13 minutes and 26 seconds, giving him an average speed of 580.93 mph. The previous non-stop record had been set by a B-29 bomber - 5 hours, 27 minutes and 19 seconds, for an average speed

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of 450.38 mph.

The two captains both landed in Topeka, were refueled and took off again. Captain Babel landed, was refueled and had his plane checked out and was in the air again in just four minutes. Over six hundred gallons of fuel was pumped into his plane during that time. Captain Smith, due to a minor repair while on the ground, took slightly longer, at six minutes ground time. Despite the refueling stop, both captains were close behind Colonel Councill. Captain Babel made the trip in 4 hours, 23 minutes and 54 seconds, and Captain Smith in 4 hours, 33 minutes and 25 seconds. All three pilots were awarded the Distinguished Flying Cross for their efforts.[79]

Captain Smith set another distance speed record a few months later. On 26 April 1946 he flew from New York to Washington D.C. in 29 minutes and 15 seconds in his P-80, breaking an eight year old record. In 1946 P-80s also participated in the famous National, Thompson, and Bendix Air Races. In the new jet divisions of these races, P-80s took home the trophies. (Which was to be expected, as the P-80 was the only functional American jet fighter at the time).[80]

But the big prize still tantalized the Air Force and P-80 pilots - the world's absolute speed record. In November 1945, word reached the Air Force that the British claimed to have set a new absolute speed record - 606 mph. General Arnold, commanding officer of the Air Force, was concerned at the implication that the British had better jet planes than America, and asked some rather pointed questions about this. The reply from the Procurement Division (naturally enough) rejected the idea that the Meteor (which the British had used to set the record) was better than the P-80. The response also pointed out that the British had conducted their test using rules that allowed the test aircraft to engage in a long, shallow dive to build up speed before entering the test circuit. It was felt that a true, level speed for both aircraft would be similar, and that a P-80

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could certainly break that record, even under more rigorous standards of level flight testing.[81]

It was felt that using the same test standards the British had, a P-80 could edge out a new speed record by a few miles an hour. However, General Arnold wanted to set a record that would last for a while, and he rejected the idea of repeating the British tests with a standard P-80. Lockheed had proposed that they be allowed to modify a standard P-80 to special high speed configuration, and they felt that such a plane could set a new record at least 30 mph higher than the British one. This would take at least 90 days.[82]

General Arnold obviously considered this matter a high priority. He ordered Lockheed to begin the modifications, but he also ordered an attempt to break the speed record with a standard P-80A. A speed test run course was set up at Muroc, and much practicing was done to find out the best ways to operate and measure the results. Extensive test results led to the conclusion that the P-80A, in its current configuration, was capable only of an average speed of 596 mph, not nearly high enough to break the record. The problem was not the amount of power from the engine but the drag encountered by the airframe.[83]

While these tests were going on, the British raised the bar again. On 7 September 1946, another British Meteor set a new record - 615.778 mph. One day later, the second XP-84 prototype, using the Muroc course, set an American speed record of 611mph. Clearly, if the P-80 was to break the record, it would the be the specially modified aircraft.[84]

The result of this modification was the P-80R - *Racey*. *Racey* made her debut in early October, 1946. Speed trials indicated an improvement over the standard P-80, but not as much as was hoped. The problem was eventually traced to the new flush intake ducts used on *Racey*. The flush ducts apparently did not allow sufficient airflow to the engine to enable it to obtain full

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power. New and larger ducts (although still more streamlined than standard P-80 ducts) were designed and installed, and *Racey* was ready to try again.[85]

Finally, on 19 June 1947, *Racey* flew the same course, and over the four runs needed to establish the measurements, set an average speed of 623.8 mph. Once again the absolute speed record belonged to the United States, and for the moment, the P-80 was the fastest thing in the sky.[86]

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1. Lopez ***Fighter Pilot's Heaven,*** p. 54.

2. McLaren, ***Lockheed P-80***, p. 36; David R. McLaren ***Republic F-84: Thunderjet, Thunderstreak & Thunderflash - A Photo Chronicle*** Atglen, PA: Schiffer Military/Aviation History, 1998, p. 14.

3. The McLaren books on the P-80 and F-84 use this method.

4. Lloyd Jones uses this method in his book on US fighters.

5. The ***P-80 Case History*** uses both the P-80A and P-80A-1 designations interchangeably.

6. Lockheed Aircraft Corporation to Col. H.A. Shepard, Procurement Division, Wright Field 11 January 1946, ***P-80 Case History***.

7. Teletype from Col. G. E. Schaetzel, Chief, Aircraft Section, Procurement Division, Wright Field, to Lockheed Aircraft Corporation, 24 April 1946, ***P-80 Case History***.

8. Routing and Record Sheet from Col. G. E. Price, Chief, Aircraft Project Section, Service Engineering Subdivision, Engineering Division, Wright Field to Armaments Officer, Aviation Ordinance Engineering Office, Wright Field, 18 January 1946, ***P-80 Case History***.

9. Col. Henry Civvellio, Acting Department for Proof Testing, Proving Ground Command, Eglin Field, Fla. to Commanding General, Air Material Command, Wright Field, 5 April 1946, ***P-80 Case History***.

10. Telegram from 1st Lt. W. N. Howell, Contract Officer, Wright Field to North American Aviation, Inc., Kansas City, KS, 26 May 1945, ***P-80 Case History***.

11. Maj. R.E. Hunt, Contract Officer, Wright Field to Lockheed Aircraft Corporation, 17 September 1945, ***P-80 Case History***.

12. Col. G.A. Hatcher, Production Section, Procurement Division, Wright Field to Lockheed Aircraft Corporation, 6 December 1945, ***P-80 Case History***.

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14. Change of Order 81 to Contract W33-038 ac-2527, 2 April 1947, ***P-80 Case History***.

15. Col. G.A. Hatcher, Chief, Aircraft Section, Procurement Division, Wright Field to Lockheed Aircraft Corporation, 17 January 1946, ***P-80 Case History***.

16. ***Aero Detail 25: Vought Corsair*** Tokyo: Dai Nippon Kaiga Co., Ltd., 1999, pp. 8, 12.

17. Gunston, ***Jet and Turbine Engines*** pp. 79-80.

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18. Wooldridge, ***The P-80*** p. 80.

19. Ian V. Hogg & John S. Weeks ***Military Small Arms of the 20th Century, 7th Edition*** Iola, WI: Krause Publications, 2000, pp. 374-78.

20. Chris Chant ***The Pictorial History of Air Warfare*** London: Octopus Books Ltd., 1979, pp. 58-9.

21. Brig. Gen. L. P. Whitten, Deputy Assistant Chief of Air Staff - 4, Washington to Commanding General, Air Material Command, Wright Field, 17 October 1946, ***P-80 Case History***.

22. Donald, ***Warplanes of the Third Reich***, p. 50.

23. Memo Report TSBPA4-4-M-48, 19 March 1947, ***P-80 Case History***.

24. Routing and Record Sheet from C. L. Hall, Fighter Branch, Engineering Division, Wright Field to Brig. Gen. F. O. Carroll, Assistant Deputy Commanding General, Engineering, Wright Field, 21 May 1947, ***P-80 Case History***.

25. Lopez, ***Fighter Pilot's Heaven***, p. 169.

26. Routing and Records Sheet from Col. A. T. Johnson, Chief, Engineering Standards Section, Engineering Division, Wright Field to P. M. Banta, Fighter Branch, Procurement Division, Wright Field, 9 June 1947, ***P-80 Case History***.

27. Larry Davis ***P-80 Shooting Star T-33/F-94 in Action*** Carrollton, TX: Squadron/Signal Publications, 1980, pp.14-5.

28. Ibid., pp. 20-1.

29. Steve Birdsall ***B-26 Marauder in Action*** Carrollton, TX: Squadron/Signal Publications, 1984, p. 6; Jerry Scutts ***B-26 Marauder Units of the Eighth and Ninth Air Forces*** London: Osprey Publishing, 1997, pp. 7-9.

30. Lopez, ***Fighter Pilot's Heaven*** pp. 19-20.

31. Davis, ***P-80 in Action*** p. 20.

32. Wooldridge, ***The P-80*** p.23.

33. Lopez, ***Fighter Pilot's Heaven*** p. 151.

34. Special Accident Report, Office of Flying Safety, Headquarters, Army Air Force, Winston-Salem, North Carolina, 24 August 1945, ***P-80 Case History***.

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35. Memo Report TSFAT5-6, 13 November 1945, ***P-80 Case History***.

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37. McLaren, ***Lockheed P-80*** p.22.

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39. Ibid.

40. Lopez, ***Fighter Pilot's Heaven*** pp. 53-4.

41. Wooldridge, ***The P-80*** p. 54.

42. Davis, ***P-80 in Action*** p. 19; McLaren, ***Lockheed P-80*** pp. 89-94.

43. Wooldridge, ***The P-80*** pp. 61, 69.

44. McLaren, ***Lockheed P-80*** pp. 49-52.

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48. Wooldridge, ***The P-80*** p. 50.

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59. McLaren, ***Lockheed P-80*** p. 79.

60. Lockheed Aircraft Corporation to Col. G. S. Garman, Engineering Division, Wright Field, 31 May 1945, ***P-80 Case History***.

61. Col. G. F. Smith, Chief, Aircraft Projects Section, Engineering Division, Wright Field to Bell Aircraft Corporation, 26 May 1947, ***P-80 Case History***.

62. McLaren, ***Lockheed P-80*** pp. 42-4.

63. Wooldridge, ***The P-80*** p. 77.

64. McLaren, ***Lockheed P-80*** p. 44.

65. Ibid., pp. 27-8.

66. Ibid., p. 28.

67. Ibid., p. 31.

68. Ibid., pp. 33-5.

69. Jablonski, ***Wings of Fire*** p. 68.

70. McLaren, ***Lockheed P-80*** p. 36.

71. Ibid., pp. 37-8.

72. Ibid., pp. 38-9.

73. Ibid., pp. 39-40.

74. Ibid., pp. 57-63.

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78. Routing and Record Sheet from Brig. Gen. L. C. Craigie, Chief, Engineering Division, Wright Field to Maj. Gen. B. W. Chidlaw, Deputy Commanding General, T-3, Wright Field, 8 November, 1945, ***P-80 Case History***.

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81. Routing and Record Sheet from Gen. H. H. Arnold, Commanding General, Army Air Forces to Brig. Gen. A. R. Crawford, Chief, Production Division, Washington, 19 November 1945, ***P-80 Case History***.

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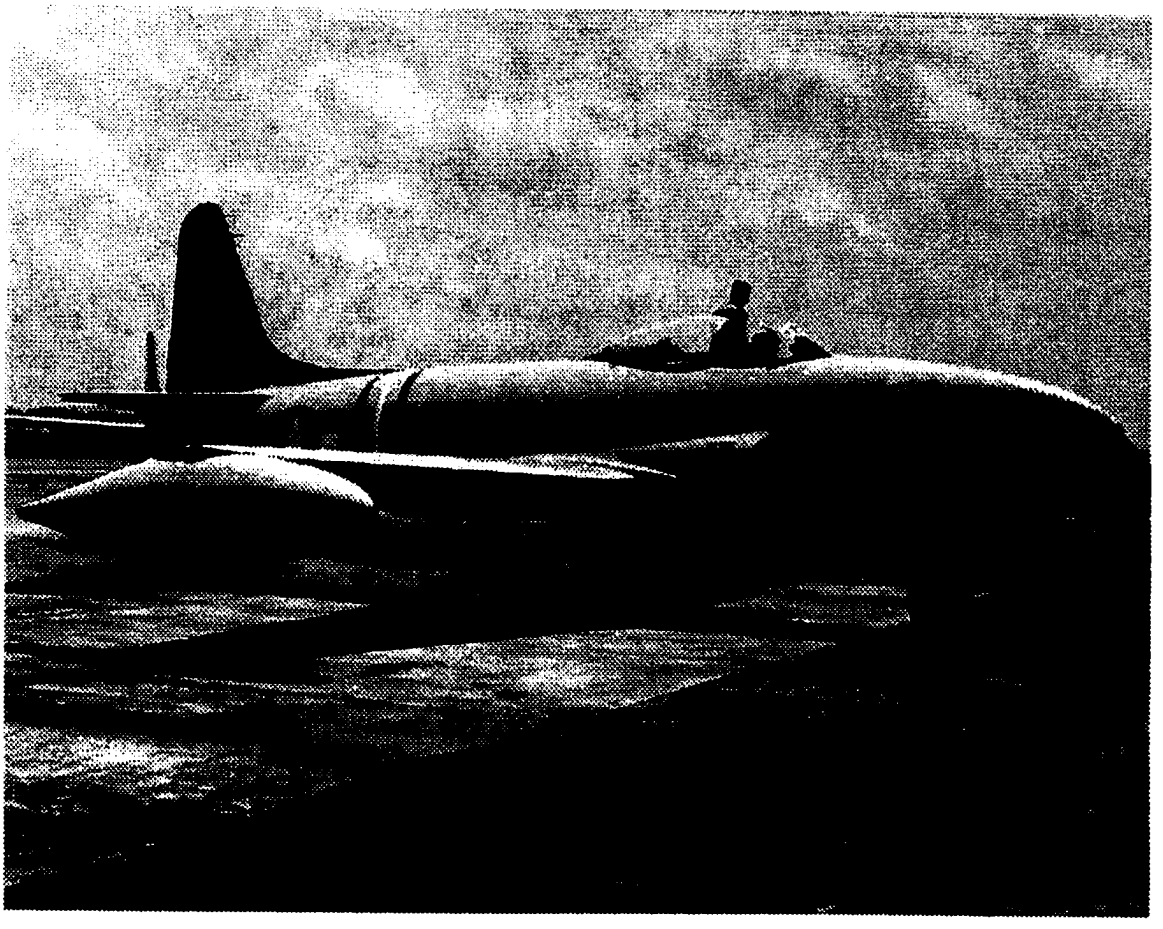
83. Col. J. W. Sessums, Assistant Deputy Commanding General, Engineering T-3 to Chief, Research and Engineering Division, Assistant Chief of Air Staff - 4, Washington, 9 July 1946, ***P-80 Case History***.

84. Wooldridge, ***The P-80*** pp. 64-5.

85. Routing and Record Sheet from Col. Albert Boyd, Chief, Flight Test Division, Wright Field to Brig. Gen. S. W. Chidlaw, Deputy Commanding General, Engineering T-3, Wright Field, 9 October 1946, ***P-80 Case History***.

86. Wooldridge, ***The P-80*** pp. 69-71.

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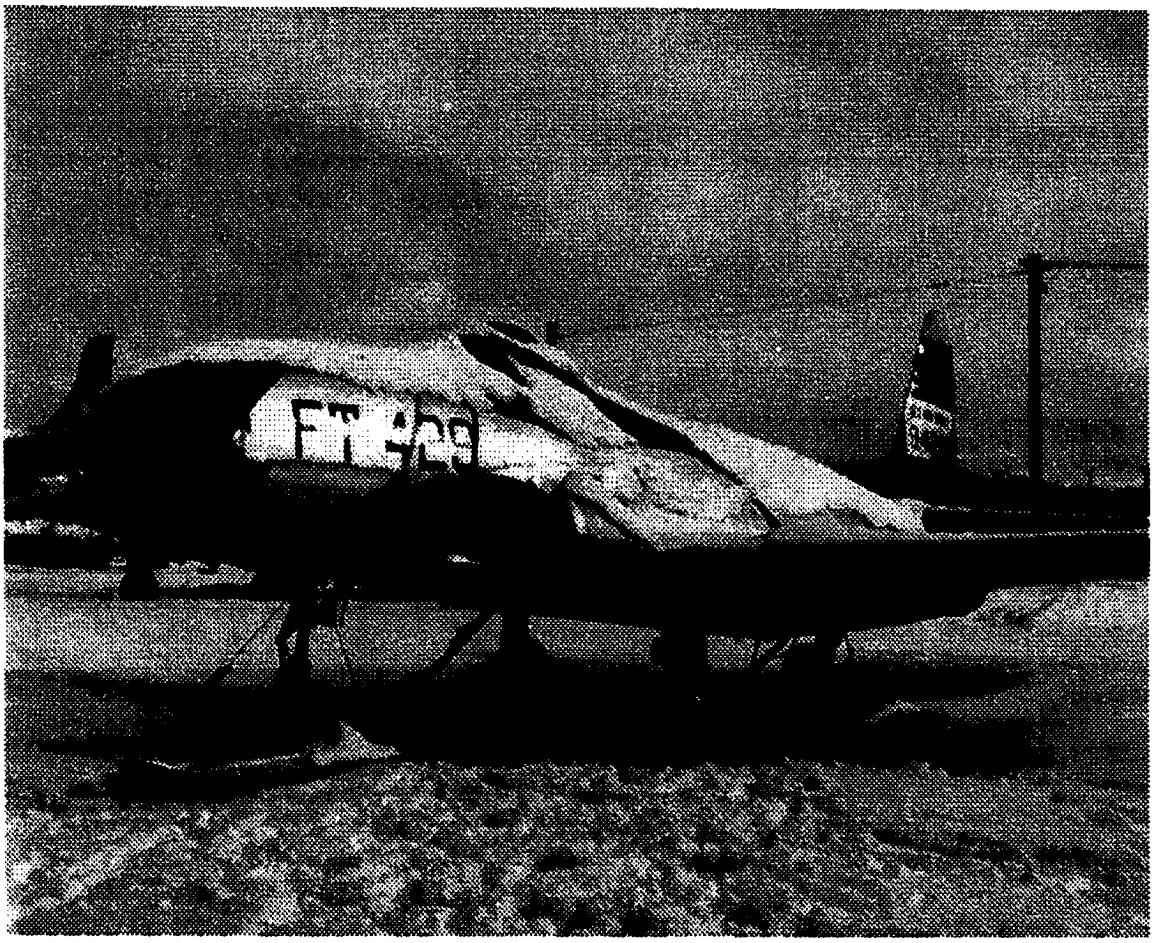
A P-80A-1 belonging to the 412th FG. This aircraft is the personal mount of Colonel Bruce Holloway, the commanding officer of the group. This photograph was taken at National Airport in Washington, D.C., during Project Comet, the first large-scale movement of jets across the country. Photo credited to James Evans, dated 19 May 1946. (National Archives, Photographic Division, Box 2029, Number 30044)

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Another picture of a P-80A-1 belonging to the 412th FG during Project Comet. This photo was also taken at National Airport in Washington D.C. The pilot of this plane was Captain G. M. Hensley. Photo credited to Captain Edward J. Ray, Office of Information Services, dated 19 May 1946. (National Archives, Photographic Division, Box 2029, Number 30050)

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An F-80C aircraft at Elmsdorf Air Force Base in Alaska. According to the original caption, this aircraft was forced to land on the tundra three years prior to the photograph. Eventually, the plane was rebuilt by Lieutenant Paul Carswell and a crew of maintenance personnel. The plane was equipped with the skis and flown out with the aid of JATO by Lieutenant Colonel William F. Benedict. Photo credited to Elmsdorf Air Force Base, Alaska, dated 15 April 1952. (National Archives, Photographic Division, Box 2029, Number 30057)

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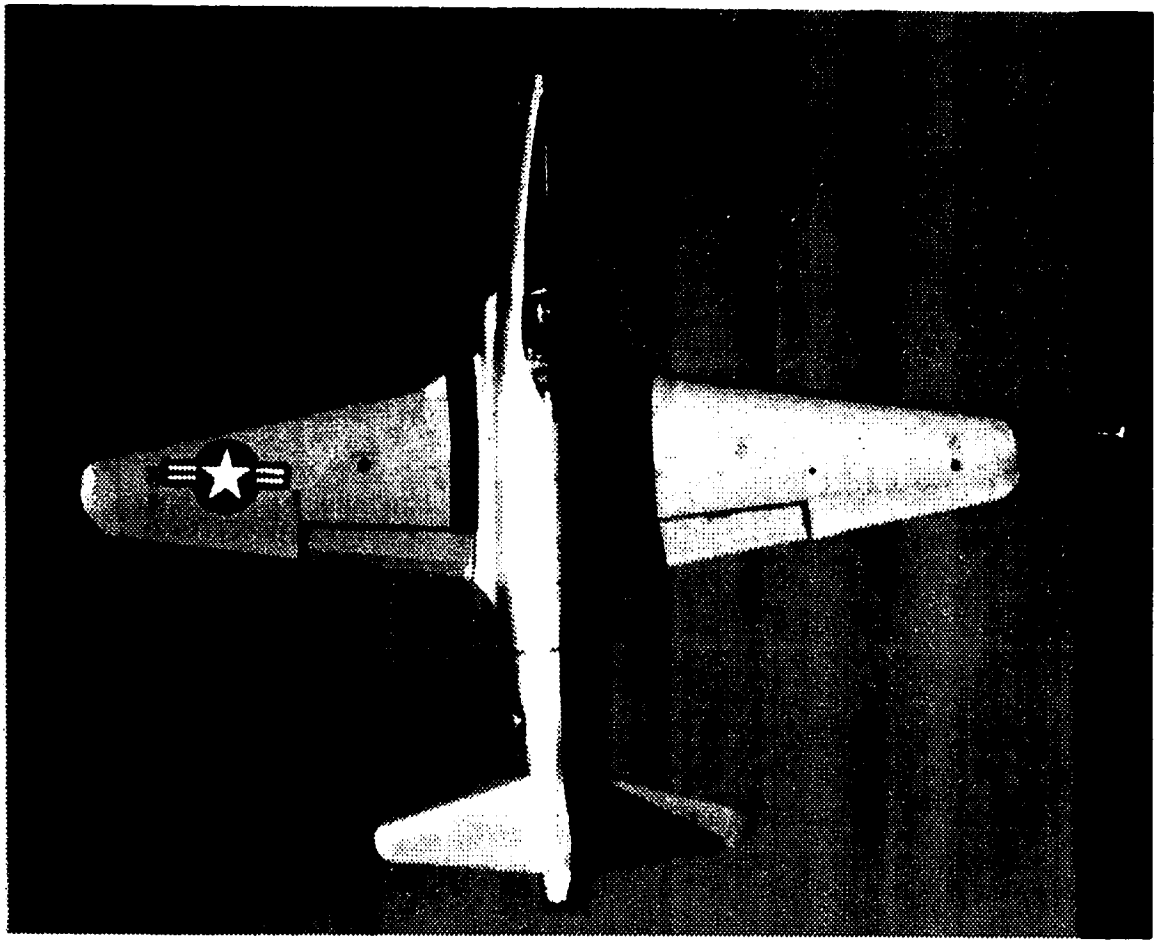
An F-80 taking off with the aid of two JATO rockets on the underside of the fuselage. Photo credited to Wright-Patterson Air Force Base, dated 7 December 1948. (National Archives, Photographic Division, Box 2029, Number 30065)

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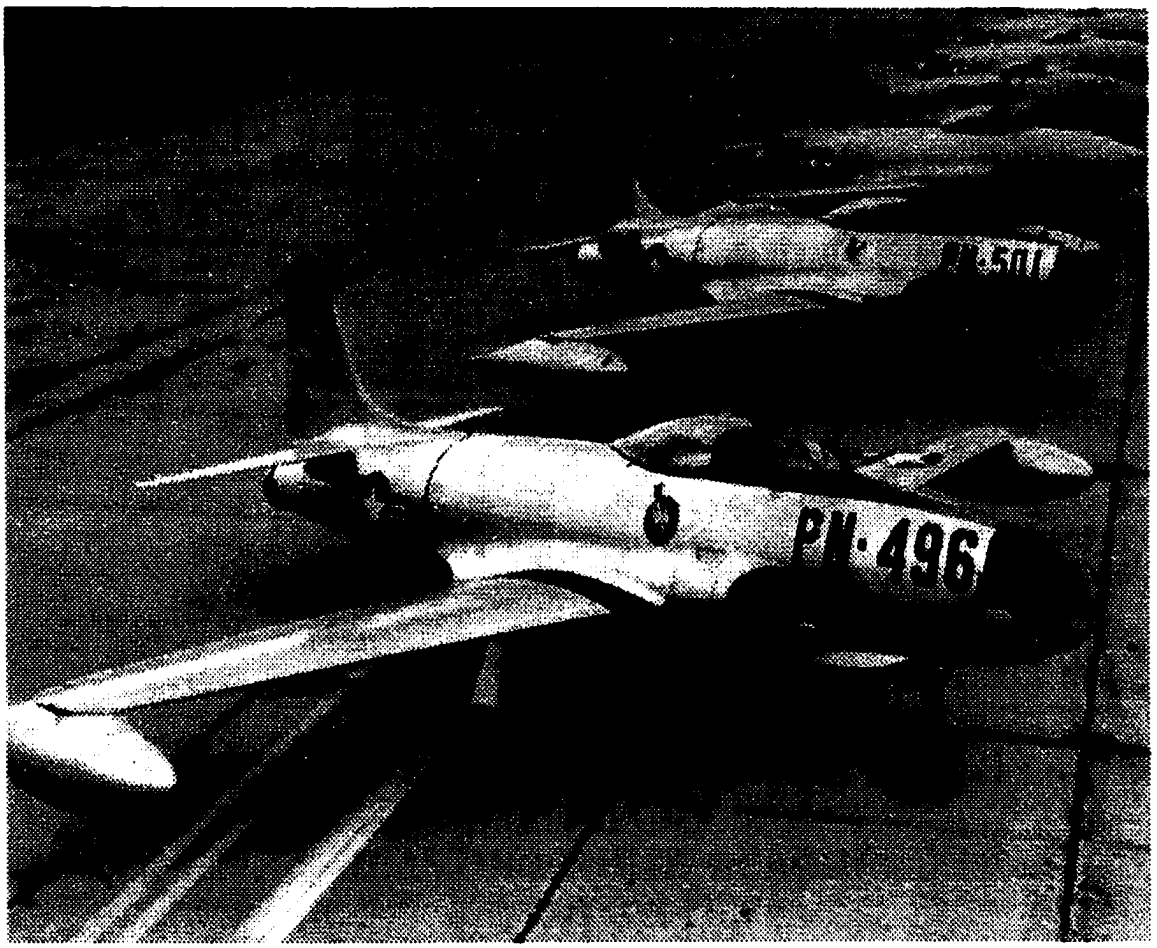
A graceful P-80 in flight, from below. Photo credited to Office of Public Relations, dated 4 February 1947. (National Archives, Photographic Division, Box 2029, Number 30072)

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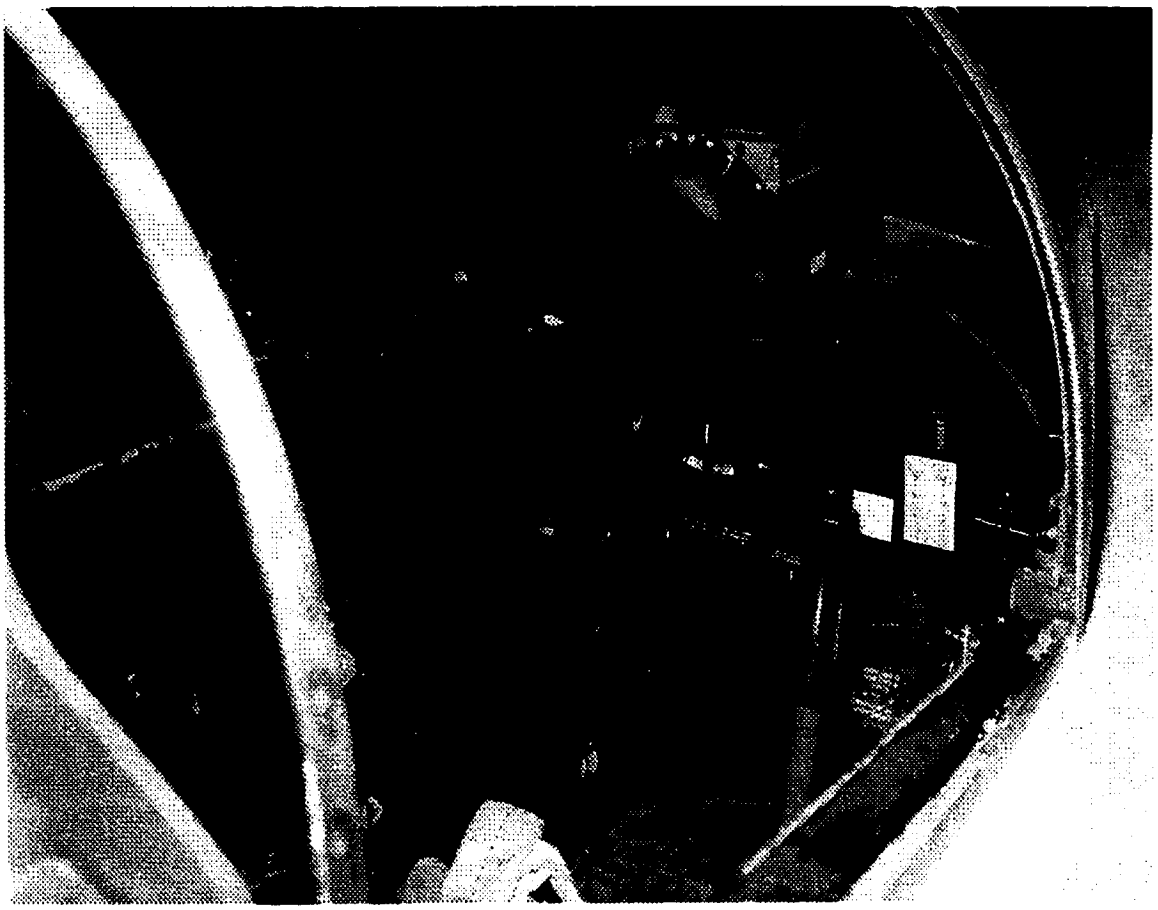
An F-80 in flight. This photo was taken by another F-80 above it, flying in the opposite direction, using what the original caption identifies as an Air Force "strip camera", of the type used for aerial reconnaissance. Photo dated 3 February 1949. (National Archives, Photographic Division, Box 2029, Number 30073)

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P-80B-1s of the 1st FG lined up. Note the sealant over the gun apertures, a practice designed to keep dust and debris out of the gun barrels. Alternately, if the guns had been removed, the openings would be covered as well. Photo credited to James Evans, Chanute Air Force Base, Illinois dated May 1948. (National Archives, Photographic Division, Box 2030, Number 30113)

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The cockpit of a P-80A. The relatively tight cockpit, with the gunsight in the pilot's face, led to a joke among pilots - you could always tell a pilot who had crashed a P-80, because he had "no Hand Hold" imprinted on his forehead. Photo credited to James Evans, Washington D.C. National Airport, dated 19 May 1946. (National Archives, Photographic Division, Box 2030, Number 30180)

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"Since the assignment of P-84B aircraft to the 20th Fighter Group, Shaw Air Force Base, South Carolina, numerous design errors and materiel deficiencies have become known, to the extent that tactical utilization of this aircraft is impossible at the present time. While it is realized that all new aircraft possess a number of materiel deficiencies, it is the studied opinion of this headquarters that poor design features of this airplane are causing safety hazards, maintenance problems, and manhour expenditures, outside of all precedents established by previous fighter aircraft."
Lt. Gen. Elwood P. Quesada, Commanding General, TAC, in a letter to the Air Force Chief of Staff[1]

Chapter 8
Problem Child: The Development of the F-84

The end of the war found Republic hard at work on the first prototype of the XP-84. Although not ready to fly before the war ended, the completed prototype emerged from the factory by December 1945. Unfortunately, as with many early American jet projects, the engine was not yet available, so the airframe was shipped to Muroc to await the arrival and installation of engine. The J35 engine eventually arrived and the XP-84 took to the skies on its maiden flight on 28 February 1946. Even that first flight was enough to confirm that the P-84 would have a measurable performance advantage over the P-80.

The J35 engine used in the XP-84 and the I-40/J33 engine used in the P-80 produced similar amounts of thrust. In fact, the early version of the J35 developed slightly less thrust than the J33 (3,750 pounds to 4,000 pounds of thrust). Since the power output of the two engines was similar, the improved performance of the XP-84 stemmed instead from its improved aerodynamics. Because the J35 engine was an axial flow, while the J33 was centrifugal, the J35 was longer and slimmer than the J33. This allowed the designers at Republic to utilize a much more slender and aerodynamically efficient fuselage on the XP-84. The XP-84 also used a single air intake on the nose of the plane, instead of the two fuselage mounted ducts of the P-80.

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The performance superiority of the XP-84 can be seen in the American attempts to set a new absolute speed record. A standard production P-80, even cleaned up for high speed flight and with a more powerful engine, was unable to exceed 595 mph, but the second XP-84 prototype, essentially unmodified, managed to reach 611 mph. High speed had been one of the Air Force's primary requirements when it initiated the P-84 program. Consequently, they were well pleased by the performance of the XP-84.[2] Other attributes of the new plane, however, would prove less satisfactory to the Air Force.

There were three P-84 prototypes. The first two were designated XP-84s, while the third became the XP-84A. This changed designation came with the addition of the J35-A-15 engine, which increased the available thrust from 3,750 to 4,000 pounds. All three prototypes were painted overall light gloss gray, similar to early P-80s, in an attempt to smooth out the surface of the plane to lessen the drag. However, the paint flaked and chipped at high speeds and from normal maintenance and usage, and as it deteriorated, the plane's performance dropped. Consequently, only the first three prototype P-84s (the two XP-84s and the XP-84A) were painted gray. All other P-84s were left in natural aluminum.[3]

Although the first XP-84 had flown at the end of February 1946, the second one was not flown until that August. Lack of an engine was again the culprit. As the third prototype was receiving a different engine, it's first flight was delayed even longer, until near the end of 1946. These delays did not pass unremarked by the Air Force.

> Engineering Division protested contractor's delay in delivering third XP-84 and the static test article. Delays were serious because many important design changes were being incorporated as "firsts" in the airplane that would be used in production airplanes later. If untried designs were put in production models, costly modifications would

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> result. This had happened in the B-29 and P-80 programs. Republic was warned that the same costly practice might "eliminate the P-84 program."[4]

Although much of the initial flight testing of the XP-84 was positive, problems did arise. An early problem, and one that would dog the P-84 program until the development of the E model several years later, was that the external aluminum skin would often wrinkle under high stress during flight. This usually occurred when the plane performed maneuvers that produced more than 6 G's of force, which was well under its designed G limits. Although the problem affected the entire airplane, the wings were especially vulnerable to it. Eventually the problem was corrected by the use of heavier gauge (thicker) aluminum for the skin, as well as by strengthening the internal structure. This might seem an obvious fix, and the question becomes why was this not done earlier?

The reason this particular solution was not adopted earlier was that Republic was engaged in a continual struggle to keep the weight of the P-84 down. From the beginning of the P-84 program, there was constant tension between the performance requirements and the weight requirements. The Air Force wanted a plane that not only had high speed and long range (both of which could best be obtained by a relatively light plane), they also wanted one capable of carrying powerful armament and large quantities of fuel, both internally and externally. These requirements necessitated a strong and heavily built airframe. The conflict between these two sets of requirements was increased by the relatively limited power of the early jet engines.

> Republic was alarmed at continued increase in gross weight. After reviewing various design changes and additional installations responsible for the increase, contractor outlined corrective action and asked Air Material Command's co-operation in preventing further increases.[5]

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Every feature or fix added to the P-84 increased the weight of the airframe, yet the available power remained unchanged. In order to keep the performance from falling off drastically, Republic took steps to keep the plane as light as possible. This included using a thinner gauge aluminum skin than they might have otherwise, to keep the weight down. Not until the introduction of the J35-A-17 engine that powered the D model of the F-84, which increased the available thrust from 4,000 to 5,000 pounds, would thicker aluminum be used to strengthen the airframe.

During the flight testing of the XP-84, Republic asked for, and was given, permission to call the new airplane the "Thunderjet."[6] This was a bid to preserve the legacy of the company's most famous design, the P-47 Thunderbolt. This tradition would continue with future Republic designs. The swept-wing redesign of the P-84, the F-84F, would be called the Thunderstreak. The photo reconnaissance version of the F-84F, the RF-84F, would be the Thunderflash. The experimental XF-91 point interceptor was known as the Thunderceptor. The massive F-105 fighter-bomber would be called Thunderchief, and would be known to its crews in Vietnam as the "Thud". And for the A-10 ground attack jet, the company resurrected the old name completely, calling it the Thunderbolt II. An apt choice, perhaps, but one generally ignored by the men and women who flew and serviced the plane. The angular lumpiness of this airplane inspired an affectionate but less historically significant nickname - the Warthog.

While testing proceeded on the XP-84 prototypes, the Air Force continued to move ahead with the contracts for the production models. The original 100 machines ordered by the Air Force had originally been divided into 25 pre-production prototypes (Y models) and 75 production machines.[7] Since the YP-84A would be essentially identical to the first production

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version, the P-84B, the Air Force eventually decided to decrease the number of Y versions from 25 to 15, and increase the production order from 75 to 85.[8]

The fifteen YP-84As differed slightly from the XP-84 and XP-84A. They were left in natural aluminum, rather than painted. They used the same J35-A-15 engine used in the XP-84A. They were the first of the P-84s to be armed, with four .50 caliber machine guns in the nose above the air intake, and one additional .50 caliber machine gun located in each wing root. This internal armament arrangement would remain the same on all straight wing models of the F-84. The guns installed on the YP-84As were of the M2 variety, despite the design calling for the newer M3 variety. The same shortage that prevented the P-80 from getting the M3 version of the gun also affected the P-84 program.[9]

Another difference between the X and Y versions of the P-84 was that the latter was given the equipment to allow the attachment of wingtip mounted external fuel tanks. Unlike the tip tanks used on the P-80, which hung below the wing, the tip tanks on the P-84 were mounted horizontally from the end of the wing. Similar to the tip tanks of the P-80, the tip tanks on the P-84 offered some increase stability and control, although they also initially contributed to a potentially lethal handling flaw in the plane. And finally, the tip tanks on the P-84 were not designed to be jettisoned in flight, but rather, if they were mounted, they were carried throughout the whole flight, eventually requiring a redesign to strengthen the mounts to allow the plane to land with full tip tanks. Later models of the F-84 had provisions for carrying under-wing, jettisonable fuel tanks as well as the tip tanks.

The various YP-84As were used to conduct the accelerated service tests, engineering inspections and for additional flight testing. They were sent to Muroc and Wright Field to

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undergo these various tests. Again, a shortage of engines and other engineering problems delayed the program, irritating the Air Force, and worrying Republic. "Production problems had delayed sending P-84 aircraft to Muroc for accelerated service tests and pilot training. AAF was concerned because 'future aircraft test and pilot transition programs were dependent to a great extent on the results of the P-84 aircraft program.'"[10]

Despite the delays, the Air Force continued to demonstrate a commitment to the P-84 program by increasing its orders for the aircraft. Before any production machines had been delivered, the Air Force contracted with Republic for an additional 141 P-84s.[11] These machines, along with the initial 85, would all be P-84B models. The only real difference between the YP-84A and the P-84B was the change from the M2 to the M3 machine guns, with their higher rate of fire.[12] Wingtip fuel tanks were usually carried, although some P-84Bs did not mount them. Subsequent models of the P-84 all carried the tip tanks as a standard feature. The same delays which affected the YP-84A also slowed delivery of the P-84B, with the first aircraft not reaching operational units until December 1947.[13]

Following the initial two production orders for the P-84B, a third contract for 191 machines was awarded to Republic.[14] Technically, the machines produced by this contract were designated as P-84Cs. The only differences between the B and C models were a redesigned electrical system in the C, and the use of a different model of engine, the J35-A-13C. Since this new engine produced the same thrust, there was no external difference between the two models of aircraft.[15] In fact, Air Force documents often refer to P-84Cs as P-84Bs. Because there was little difference between the two versions of the plane, the P-84C displayed all the problems associated with the P-84B.

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Those problems were numerous and severe. Although no one problem was catastrophic in and of itself, taken as a whole, they were significant enough for the Air Force to give serious consideration to canceling the entire P-84 program, something that occured with no other early production jet fighter. It needs to be stressed that, first, these problems were not simply the usual process of eliminating the "bugs" from a new design. That is a normal and expected part of any aircraft's development, and was recognized as such by the Air Force. It should also be pointed out that the problems with the P-84, although largely stemming from Republic's design of the plane, were certainly not caused by any malice or negligence on the part of Republic. After all, the company saw this plane not only as its ticket into the jet age, but on an even more basic level as its means of survival. They were hardly likely to deliberately jeopardize such a project.

The various problems of the P-84 arose from two basic causes. One has already been mentioned - the effectively contradictory set of requirements the Air Force issued for the plane, demanding high speed, long range, and heavy armament all with a fixed and relatively limited amount of power. The other root of the P-84's problems lay in the fact that these new jet fighters were exploring the realm of high speeds, approaching the speed of sound. It was recognized that there would be unforseen difficulties as designers ventured into these unknown and untested areas. It was the misfortune of the P-84 that Republic's attempts to fulfill the Air Force's design requirements produced a plane that was particularly susceptible to these problems.

Lacking high speed supercomputers to model designs for them before they were built, the only way for aircraft designers of the period to discover flaws and problems with their designs was to actually build and fly them. Even wind tunnel testing on models and full sized mockups could not reveal all the potential problems. So most of the problems with the P-84 were

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discovered the hard way - by experience and accidents.

As part of their ongoing attempts to overcome the limitations of the P-84, Republic's engineers proposed and developed a system that they felt would enable the plane to produce additional power with the same engine. The water injection system used in other aircraft has been mentioned, but that was of limited utility due to the brief time it could be used before damaging the engine. In fact, attempts to use water injection to boost the speed of the second XP-84 to enable it to set a new speed record only resulted in two destroyed engines (fortunately in ground tests).[16] Republic's engineers felt they had a practical alternative - a system that they called a "tailpipe burner assembly." The concept was simple - raw fuel would be injected into the stream of exhaust gas as it exited the tailpipe. The high temperature of the gas would ignite the fuel, adding this combustive effect to the overall thrust, increasing the power available. Unlike the water injection method, this technique, properly done, was limited only by the available fuel. Although this system would not actually be used with the F-84, once the concept was proven, the "afterburner" would become a standard element of virtually all high performance jet aircraft from that point on.[17]

One category of problems experienced by the early P-84s was a shortage of support equipment. For an air unit to be an effective combat force, it needs more than just the airplanes. Components of airplanes break and wear out, producing a need for spare parts of all types, up to and including entire engines. Special tools are often needed to remove access covers or work on the plane's inner systems. Engine stands are needed to facilitate removal and maintenance on or replacement of an engine. Since the engines of the new jets were located to the rear of the plane, it was a standard design feature of many of the early jet fighters to design the fuselage to be

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removable just behind the wings. This allowed the maintenance crew relatively easy access to the engine. However, this procedure also required special stands, or cradles, to hold the removed tail assembly during the procedure. There were also other special items, unique to the new jets.

Prior to the development of jet fighters, the standard method for the pilot to enter the cockpit was to have him climb onto the wing, sometimes with the aid of a special retractable or concealed step, and then climb in. But the new jets such as the P-80 and P-84, with the engine in the rear rather than the nose of the plane as was standard for piston-engined aircraft, had moved the cockpit forward. Although this provided the pilot with much improved visibility, it also meant that since the cockpit was in front of the wing, he could no longer use the wing to mount the plane. Instead, specially designed ladders had to be provided to enable pilots to enter and exit the aircraft.

Also, it had become standard practice by this time to start jet engines on the ground by using an external power source. It took a great deal of power to get the compressor up to operational speed, as well as to operate the other elements of the engine. While it was possible to do this with the jet's own battery power, it was easier and safer to provide the power from an external source. Consequently small mobile "starter carts" had begun to become standard elements for any jet equipped unit.

Most, if not all of these pieces of specialized equipment were in short supply, at best, when P-84s were first assigned to combat units. The lack of the proper engine stands and starter carts, in particular, could effectively cripple a fighter unit by making it difficult or impossible to perform necessary maintenance or even start the aircraft's engines. These difficulties were documented in General Quesada's letter to the Chief of Staff:

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> ...To date, approximately four months after receipt of the aircraft, only ten engine stands have been received at Shaw Air Force Base, where fifty-three are required to perform the maintenance function. Air Material Command now advises that the additional engine stands will not be available for three to six months. Many P-84 aircraft of the 20th Group are waiting six days in an "out of commission" status for the twenty-five hour engine inspection, due to shortage of engine stands.
>
> b. Thirteen tail cradles for removal of the aft fuselage section are on hand at Shaw Air Force Base, but in order to perform the maintenance function, a minimum of thirty-nine are required.
>
> c. Thirty-eight C-22 external power units are authorized for a group of P-84 aircraft, on the basis of one power unit per two aircraft. Only one C-22 power unit is required to start the J-35 engine; however, due to non-availability of the C-22, C-16 power units have been substituted. Two C-16 power units connected in series are required to start each J-35 engine. In order to maintain the same tactical efficiency then, seventy-six C-16 power units are required, but the authorization stands at thirty-eight.[18]

This shortage of crucial support equipment for the P-84 is perhaps the least excusable of the early problems experienced by the aircraft. Deliveries of the plane were well behind both the Air Force's and Republic's schedule. Given these delays, the necessary support equipment should have been readily available, but was not. Shortage of support equipment was far more critical in delaying effective operation of the P-84 than almost any other factor, but it was also the easiest of the problems to correct - simply produce and distribute the needed equipment.

Maintenance problems were affected by more than a shortage of equipment, however. The early models of the P-84 were considered by maintenance personnel to be extremely difficult to work on. In the words of Colonel M. E. Glaser, Deputy Chief, Maintenance and Supply Division, the plane was a "Mechanics' Nightmare."[19] While some of this may have been due to the shortage of both spare parts and trained maintenance personnel, much of it was due to

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awkward features of the P-84's design. Again referring to General Quesada's letter:

> Maintenance Difficulties: a. Engine Installation. In order to remove and reinstall the engine in the P-84, dive flaps must be moved, followed by inner and outer sections of the air ducts forward of the engine. Removal of these sections of the air ducts necessitates removal of fifty-two Dzus fasteners and four screws, most of which are extremely inaccessible. A mechanic must stand in a half crouched position and connect or disconnect the plumbing from the accessory section by "feel". This procedure is extremely difficult and requires a great amount of lost time for completion of the simplest movements of a wrench or screw driver. Since enough spare parts for engine build up are not available, the new engine must be built up after removal of the old engine and by utilization of hydraulic pump, aspirator, and plumbing from the old engine. In order to check for proper adjustment of accessories and leaks, after installation the air ducts must be reinstalled so that the engine may be operated at 100% RPM. If repair of leaks or adjustment to any accessory other than the governor or main fuel filter is required, removal of the duct is again necessary. Because of this feel and guess method of maintenance, in the accessory section, an average of seventy-two manhours are required for the twenty-five hour engine inspection and engine change. The principle of visual inspection by the mechanic of each step of his own work and by technical inspectors, after completion of maintenance, was completely ignored in the design of the forward fuselage of this aircraft. This is especially significant since it involves safety, particularly regard to high pressure fuel lines.
>
> ....Replacement of the battery relay, which is frequently necessary, requires removal of the nose section radio equipment, batteries, and center section of the air ducts. This involves approximately sixteen manhours.
>
> ...In order to change the reverse current relay, the engine must be removed after the usual procedure of removing dive flaps and air ducts, thus transforming a relatively simple replacement of a small part into a major maintenance function.
>
> ...The canopy, canopy support deck, and main fuselage fuel cell must be removed to permit access to the oil tank. This requires from twenty-five to thirty manhours for removal and reinstallation.[20]

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Although it may have seemed like it to mechanics trying to change the engine of a P-84, the designers at Republic had not gone out of their way to make servicing the airplane difficult. They were simply, once again, trying to satisfy multiple conflicting design requirements in one package. The Air Force itself was responsible for much of the problem.

> Colonel Glaser ... wanted to know if discrepancies he outlined had been noted by Maintenance Div. Personnel during mock-up and 689 inspections, and if so, what corrective action AMC was taking. General Stowell replied ... that AMC had reported numerous potential maintenance difficulties at the time of the 689 Inspection in December 1946 but that board members had vetoed many of the requested changes in order to maintain a "clean" airplane and/or to facilitate production.[21]

To Republic's credit, they worked hard to correct the various maintenance difficulties, fixing many of them in the D model, and most of the rest in the E version.

The equipment shortages were crippling but temporary, while the maintenance problems were frustrating and time consuming but not in themselves enough to cancel the program. It was the problems with flight characteristics that would nearly end the P-84 program. The first of these has already been mentioned - the wrinkling of the skin of airplanes at high speeds and/or under high stress. These problems forced the Air Force to order pilots flying the P-84B/C not to exceed 450 mph, .8 Mach, or 5.5 G's while flying - restrictions which rather defeated the purpose of a high speed fighter plane.

Added to the wrinkling of the skin was an even more serious problem of cracks developing in the wings. This problem eventually required the Air Force to issue an order grounding all P-84Bs and Cs until they could be inspected.[22] If the inspection revealed the cracks, they were sent back to Republic for rebuilding. If there were no cracks, then the planes were

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released to flying status, but with additional restrictions on speed and G loads. The D model strengthened the wings somewhat, allowing an easing of these restrictions, but not their cancellation. Not until the E model were the wings considered to be structurally sound enough to eliminate the restrictions.

Beginning after the initial production order of 85 machines, the P-84B and C models used retractable attachment points for external ordnance - bombs and rockets. Again the attempt to reconcile high speed with heavy firepower can be seen. Two large retractable mounts were installed, one on each wing just outboard of the fuselage, to hold bombs or external fuel tanks. Four smaller stubs for rockets were installed, two per wing, outboard of the landing gear. Each rocket stub was to hold two 5" HVAR rockets. Problems with both systems were encountered almost at once.[23]

The desire to have the mounting points retract into the wings limited their length to no more than the thickness of the wing, and made the mounts more complex than they would otherwise be. The rocket stubs exhibited numerous glitches in their electrical fire control systems, causing premature and out of sequence launches. This destroyed whatever accuracy the rockets had to begin with, and the retractable stubs were eventually replaced with removable hardpoints. The new mounts held and launched the rockets far more reliably than the original retractable ones had done.[24]

The bomb mounts were a greater problem. These were also limited in size by the need to retract into the wing. In this case, the small size would prove to be a major problem. It was rapidly discovered that, when carrying bombs, especially larger ones (over 250 pounds weight), on these retractable mounts, the plane had a tendency to nose up, requiring the pilot to use full

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nose up trim and substantial extra force to hold the plane level. When the bombs were released, the plane underwent a violent nose down motion, partly due to the reversal of forces, and partly from the previous compensation for the nose up tendency. These characteristics limited the early P-84s to carrying bombs of no more than 250 lbs, and to stay under 450 mph during bombing runs. Again, the limitations of the design were defeating the intended purpose of the airplane.[25]

The problem with the bomb racks was eventually found to be that they were too short. When bombs were hung from them, the bombs were close enough to the fuselage to disrupt the airflow, thus causing both the nose down and nose up tendencies. The solution was straightforward - replace the retractable mounts with longer, removable ones. Once this was done, the control problems with the P-84 on bombing missions largely disappeared. Later models of the F-84 would be capable of carrying two 1,000 lb bombs and delivering them with considerable accuracy.

Problems were also encountered with the canopy of the P-84. More specifically, the canopy would occasionally either come open or worse, tear loose during flight. The sliding open problem was more a problem of procedure than of malfunction. The canopy was closed and locked electrically. Two small electrical micro switches cut the electrical power when it was shut. But if the switches did not line up properly with their intended receptacle points, the electric closing assembly kept grinding away until it had stripped its own gears. This made it fairly easy for the canopy to accidentally come loose and slide back during flight.[26]

The other problem, that of the canopy blowing off during flight, was more serious and took a while to solve. Because of the high altitudes at which the P-84 was to operate, the cockpit was pressurized using air from the compressor on the engine. But the original canopy of the P-84

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was essentially just a World War II era bubble of Plexiglas, never intended to deal with pressurization. So occasionally, especially if greater than intended pressure was being created in the cockpit, the excess pressure would prove too much strain for the canopy, and it would simply tear loose. The G model of the F-84 largely solved this problem with two features. One was a series of reinforcing strips on the inside of the canopy, to strengthen it, and the other was an overpressure "blow panel," designed to give way and relieve the excess pressure before it affected the entire canopy.[27]

The layout of the engine in the P-84 made the plane especially susceptible to tailpipe overheating. Because the air intakes had to bend around and under the cockpit tub, the front of the engine was angled slightly (4 degrees) downward to facilitate airflow. This meant that the tail pipe had to be angled downward as well, to enable the exhaust to exit horizontally. The resulting "kink" in the tailpipe ducting was especially susceptible to minor leaks, and then a small but extremely hot quantity of exhaust gasses would be released inside the rear fuselage. When this occurred, the pilot needed to land the plane as soon as possible, to prevent serious damage to or destruction of the airplane.[28]

Another problem, an extremely serious one observed in several P-84Bs during early 1948, was to have an entire wing rip off during flight. This happened to three P-84Bs, one each at Eglin, Dow, and Shaw Air Force Bases. All three accidents destroyed the planes, but miraculously, only the pilot of the P-84B at Eglin, Major Si Johnson, was killed. The accident which killed Major Johnson is recounted in Donald Lopez's book, ***Fighter Pilot's Heaven***. Captain Lopez was part of the same flight as Major Johnson, and witnessed the accident. The accident took place during a "Firepower Demonstration," at low altitude in front of a large

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audience.

> "Roger. We'll hit them just in front of the stands," Si answered. He started a slow descending turn to get into position. When the bombers crossed the boundary of the range, we nosed down into a steep dive to the north and then swung to the right into a curve of pursuit on the bombers. As we completed the pass, we began a steep climbing turn to the right. I thought that it must have looked great from the stands, because Si had timed it right on the money. It's always a good feeling when a mission goes like clockwork.
>
> The good feeling was short-lived, however. My eyes were glued to Len's P-80 when, suddenly, from the corner of my eye, I saw Si's P-84 disintegrate. The pieces hurtled into the ground, sending up a tremendous cloud of dust and debris. It happened so fast that I couldn't believe my eyes. My first thought was that he must have collided with another airplane, but we were past the B-29s and our three P-80s were intact. I yelled into the oxygen-mask mike, "What happened, Len?"
>
> "Beats the hell out of me," he replied. "The plane just broke into pieces. Si didn't have a chance." Just then range control broke in and tersely ordered all planes to return to Eglin and land. I took the lead, and we proceeded back to the field in stunned silence.[29]

Similar accidents during two other airshows happened shortly after, although at higher altitude, which allowed the pilots an opportunity to react and escape the aircraft.

This problem, combined with the earlier instances of wrinkled skin and stress cracks in the wing, caused the P-84s to be grounded, inspected and restricted - 400 mph and less than 6 G's (Major Johnson had been flying at 500 mph and pulling up in a tight turn when the accident occurred).[30] Eventually the problem was traced to a specific effect on the aerodynamics produced by the wingtip fuel tanks.[31]

When the P-84 did a high speed turn, especially with empty tip tanks , the airflow around the tip tanks induced excessive lift on the upper wing. This lift would very quickly tighten the

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turn, without giving the pilot the time to react or correct. This ever increasing turn would overstress the wing, inflicting forces far in excess of what it was designed to bear (early P-84s were intended to withstand an ultimate stress load of 11 G's, later models 13). That much stress occurring that quickly simply ripped the wing off.[32]

Ironically, once the cause of the accidents was known, the solution proved to be quite simple. A small triangular metal fin was attached to the outer side of the rear of both tip tanks. This fin increased stability, and prevented any similar accidents. The fin was retrofitted to earlier P-84s as well.[33]

Throughout all the troubles, Republic continued its efforts to improve the P-84. By the end of 1947, although considerably behind schedule, the first deliveries of P-84Bs to combat units were being completed, P-84Cs were beginning to be produced, and a new and improved version was ready to be produced. This new version was to be the P-84D, and would feature a number of improvements. These included the new J35-A-17 engine, with 5,000 pounds of thrust, thicker gauge aluminum skin, and a forward hinged cover for the nose armament bay. Previous models had required the entire panel to be removed to service the guns, an awkward and potentially dangerous task. Several "fixes" were incorporated into this version, including the triangular fins on the tip tanks and the longer, detachable bomb racks under the wings.[34]

Despite considerable misgivings about the performance of the P-84 to date, and not without some rather strong dissenting opinions, the Air Force agreed to purchase an additional 154 copies of the new version of the fighter, substituting them for earlier versions previously contracted for.[35] At least part of this decision stemmed from a desire to preserve Republic as a defense contractor. Republic's finances had been very shaky ever since production of the P-47

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had ceased, and the seemingly endless problems and delays with the P-84 just made the situation worse. At one point, Republic had even been forced to ask the government for a loan, as they had only enough cash for three more week's operation.[36]

Following closely on the heels of the P-84D, Republic proposed another version to incorporate still more improvements. This would be the P-84E. This new model was to have a lengthened fuselage and larger and roomier cockpit, strengthened wings, a radar ranging gunsight, new radio equipment, larger tip tanks (230 gallons compared to 185) and the elimination of most of the maintenance difficulties experienced with the earlier versions. The Procurement Division somewhat reluctantly advised approval, acknowledging the difficulties with earlier versions, but noting the improvements and stating the desirability of preserving Republic as a defense contractor. Cancellation of the P-84 would likely result in Republic going out of business.[37]

The summer of 1948 not only saw the change in designation of Air Force fighters from P to F, it also saw the results of the early efforts to bring the P-84B into effective squadron service. The results of these efforts were so disappointing that they prompted the letter from Lieutenant General Quesada to the Chief of Staff. General Quesada had commanded the 9th (Tactical Ground Support) Air Force during World War II, and was one of the few senior Air Force officers who favored planes other than the attention-getting strategic bombers. So when General Quesada said that "The deficiencies described above are known to be of such a serious nature that unless major corrective action is undertaken, units equipped with this aircraft will remain at a combat potential of near 'zero.'",[38] he had to be taken seriously.

The problems with the P-84 were hardly unknown to the rest of the Air Force. The following are excerpts from the report of Air Proving Ground Project No. 6478-4-5, *Operational*

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Suitability Test of the F-84B Airplane.

3. CONCLUSIONS:

a. The F-84B does not perform satisfactorily any of the following missions:

(1) Fighter-Bomber.
(2) Escort-Fighter.
(3) Ground-support Fighter.
(4) Interceptor-Fighter.

4. RECOMMENDATIONS:

It is recommended that:

a. A study be made to determine the feasibility of modifying the F-84Bs now produced to enable the airplane to perform satisfactorily a combat or training mission.

5.DISCUSSION:

b. Structural Failures: The wing construction of the F-84B has been the main source of difficulty with the airplane. Pulled rivets, wing wrinkling and buckling were encountered when the airplane was submitted to loads greater than 6 "g" at speeds in excess of 400 mph IAS [Indicated Air Speed]. All aircraft exhibited these inherent weaknesses. Structural failures necessitated replacing the wings of three aircraft, and less severe indications of failure were apparent on the other two. The airplane was limited to a 6 "g" acceleration and speeds less than 450 mph IAS, which precluded an low-level, high-speed tactical operation because of the high wing-loadings encountered in the performance of such missions. It was found that pilots often inadvertently exceeded this limit during pullout regardless of their awareness of the restriction. Only limited bombing and armament testing could be conducted because of the structural limitations and failures.

Pilot attitude toward flying the airplane was greatly affected by these failures. Pilots exhibited great reluctance to fly the aircraft and this prejudiced the airplane-pilot performance combination.

h. Armament: In APG Final Report, Project No. 6484-2-5, subject, "service Test of the Armament Installation on the F-84B Airplane," dated 29 October 1948, it was concluded that the armament installation in the F-84B airplane is functionally unreliable and tactically unsuitable for Air Force use. 62,553 rounds of .50 calibre ammunition were fired. The following are a few of the discrepancies noted:

(1) Gun installation, ammunition loading, and boresight adjustment require excessive time and manpower. Approximately 2 man-hours are required to reload and install ammunition containers

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> and properly service the gun access doors.
>
> (2) Excessive fumes and noises from gunfire enter the cockpit and make it uncomfortable for the pilot...
>
> (4) A lateral oscillation was induced by over-controlling when pilots attempted to make sighting corrections during firing runs on air-to-air and air-to-ground gunnery missions. In tracking a moving or stationary target in rough air this effect is so exaggerated that maintaining the sight pip on the target is extremely difficult....
>
> k. Maintenance: The overall maintenance of the F-84B aircraft requires approximately three times the number of man-hours required to perform similar maintenance on the F-80A-5 airplane. The requirement of special tools, lack of access doors, and location and installation of units and accessories make even routine maintenance...difficult. [39]

Nevertheless, it was General Quesada's letter that was the catalyst for a serious evaluation of the entire P-84 program. Lieutenant General Chidlaw of Air Material Command wrote a response to General Quesada. In it he agreed that the P-84 had many serious problems, that compromises and sacrifices had been made on maintenance features to achieve performance goals, and that much corrective work needed to be done to make the P-84 an effective airplane. He felt that both the Air Force and Republic needed to do a better job, and said that Republic had been "forcibly warned that the P-84 was considered unsatisfactory" and that a greater effort had to be made to correct problems.[40]

The problems with the F-84 were so widespread and debilitating that the Air Force took the unprecedented step of convening a conference at Republic's headquarters. This conference took place from 29 September to 1 October 1948, and included representatives from the Headquarters of the Air Force, Air Material Command, Republic Aviation, the Department of Commerce, the Bureau of Standards, NACA, commanders of F-84 tactical air units, Lockheed Aviation, North American Aviation, and pilots who had survived F-84 crashes. This conference

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was to produce a recommendation about the future of the F-84, and with it, Republic Aviation.[41]

There was a significant element in the Air Force that favored cancellation of the F-84 project. Three models of the plane had been produced so far, and none of them was considered an effective and satisfactory combat aircraft. Many felt that the F-84 was a mistake, and that the Air Force should just cut its losses. A Staff Study from the same period outlines the proposed actions regarding the F-84:

> Recommendations were to: (1) accept all "B", "C", and "D" production, but to cancel the F-84E contract; (2) activate 78th Fighter Group with F-80's; (3) assign 15 or 20 F-84B's and "C's" to ATC for testing as to suitability for flying training; (4) place remaining "B" and "C" aircraft in storage; (5) convert fighter groups from F-84's to F-51D and F-47 aircraft. Staff Study concluded that only a major retrofit program could make F-84B and "C" aircraft operational, and that, even with structural changes the F-84 would never "satisfactorily perform the missions of any of the three major air commands."[42]

Canceling the F-84E contract would also save the government approximately $20 million, a significant sum, especially in an age of sharply limited budgets.

Despite strong arguments for cancellation of the F-84, the eventual consensus of the conference was that the F-84 program should be continued. A majority of the attendees at the conference felt that the basic design of the plane was sound, and that if the bugs could be worked out, as the E model seemed to offer, it would be a worthwhile combat aircraft. This was not the final word on the F-84 program, however. On 26 October 1948, the Vice Chief of Staff had "directed AMC to investigate the F-84 situation and to cancel F-84 procurement if deficiencies could not be corrected."[43]

The recent conference was used as a basis for the Air Force's decision. Not only had

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Republic promised that the latest version would eliminate the serious problems, but the representatives of the other manufacturers present had confirmed that they had been forced to dealt with similar problems when developing their own aircraft designs. Although the $20 million allocation for the F-84E would be saved if the program was canceled, more than three times that amount had already been spent on the entire F-84 program. If it were canceled, that money would have been spent for no practical return.

And finally, if the entire contract were canceled, it was highly probable that Republic would be forced out of business. Although the company had attempted other aircraft designs, none had achieved any commercial success, and so the company was almost totally dependent on the F-84 program for its financial well being. Republic was an important defense contractor, and the government was reluctant to have them disappear if anything practical could be done to salvage the situation. Given the severity of the problems encountered with the F-84, however, it is highly probable that the government would have canceled the contract if fairly strong evidence of the improvement of the design had not been available.

The decision was made to continue with the production of the F-84E, to thoroughly evaluate it once the first examples were available, and to completely retrofit surviving examples of the earlier B, C, and D models to bring them up to the standards of the E. However, 100 of the planned F-84Es were canceled, and the money saved allocated to the upgrade of the earlier machines. Also, an additional 567 F-80Cs were ordered by the Air Force, as a hedge against a shortage of F-84s.[44]

The decision to purchase the F-84E was finalized on 29 December 1948, when the official contract for 409 planes plus spare parts was authorized by the Air Force.[45] Delivery of the new

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plane was to commence at the end of March 1949. Like virtually every other aspect of the F-84 project, the F-84E was late, but less so than the other models had been. The first F-84Es were delivered on 18 May 1949.[46]

The F-84E did prove to have corrected most of the problems. The lengthened fuselage actually gave superior performance over the F-84D, despite the fact that the two models used the same engine. Both maximum and cruising speed increased with the E model. The cockpit was larger, and the instrument layout had been modified to make it easier to read. The wings had once again been strengthened, and this largely eliminated the structural problems with the earlier model machines. It took several extra years and four different models, but the Air Force finally had a combat worthy F-84.

This did not mean the end of the problems for the F-84 program, however. Problems with the gunsight persisted for several years. The canopy remained a problem until the development of the G model several years later. The takeoff run of the airplane remained extremely long, and so beginning with the F-84E provision was made for the attachment of two 1,000 pound thrust JATO units. Units transitioning to the F-84E experienced delays due to slow delivery of new machines and shortages of spare parts. But these were relatively minor troubles compared to the problems of earlier models.

The F-84 was finally delivering its anticipated performance, but the Air Force recognized that the F-84 was no longer the ultimate expression of speed and performance. Newer fighters, especially those with swept back wings such as the new North American F-86A Sabre, had already eclipsed the speed records set by the F-80 and F-84. Thus the Air Force considered the F-84 to be only an "interim" penetration fighter and interceptor. The decision was made to retain

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the F-84 as an interceptor / penetration fighter pending the results of the competition between the next generation of penetration fighter prototypes - the XF-88, XF-90, and XF-93.[47]

The F-84E may not have been the ultimate air superiority fighter the Air Force had originally hoped for, but it did reveal considerable potential for tactical ground attack missions. The new longer bomb racks had completely cured the nose down/nose up problems of earlier models when carrying bombs, and the strengthened wings made the plane much better able to endure the stresses of high speed bombing runs. In tests the F-84D and E compared very favorably with the F-80C as a ground attack aircraft. The two were very similar in most characteristics. The one strong advantage that the F-84 had over the F-80 in ground attack missions was its ability to carry both bombs and external fuel tanks. At that time, the F-80 could only carry external stores on the wingtip brackets, creating a "bombs or fuel" dilemma. This gave the F-84 approximately three times the range of an F-80 when carrying bombs. It should be remembered, however, that both aircraft were considerably inferior to piston-engined planes in terms of range and mission "loiter time."[48]

Republic recognized the limited performance of the straight-winged F-84, and on 26 February 1949, proposed modifying one or more of the F-84Es then on the production line to give increased performance. Modifications would include "(1) improved APG-3 radar set and locating of antenna in nose of airplane; (2) tail pipe burning installation; (3) replacement of wings and tail surfaces with swept back wings and tail surfaces; (4) installation of flush air intakes in side of fuselage for engine air; and (5) rework of landing gear to fit in swept wings."[49] The Air Force proved receptive to the idea, however, they felt that such modification would result in what was essentially a new aircraft. They also felt that Republic's proposed schedule for the delivery of

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such a prototype was overly optimistic.[50]

Ultimately, several F-84Es were modified to the new swept-wing configuration. These aircraft did have considerably increased performance, and were ordered by the Air Force as the F-84F Thunderstreak. As the first production versions of this aircraft were not delivered until late 1952, and engine shortages delayed completion of most of the first production batch until 1955, this model is outside of the consideration of this work. Only a brief description of the prototype will be included.

The original YF-84F was a moderately modified F-84E. It was delivered to the Air Force in May 1950. The most obvious difference was the wings. Instead of the straight wings of the F-84E, the YF-84F had wings swept back at a 40 degree angle. The tail and horizontal stabilizer were also swept back. As the YF-84F had the same J35-A-25 engine as the F-84E, but significantly increased weight, flight tests proved it to be considerably underpowered.[51]

The decision was made to power the next two F-84F prototypes with the English Armstrong Siddeley Sapphire engine, which generated 7,200 pounds of thrust. This engine would be manufactured under licence in America by Curtiss Wright as the J65. The J65 was a larger engine than the J35, which required the fuselage of the YF-84F to be deepened. This was the beginning of a process that saw the F-84 and F-84F grow further and further apart. Republic had originally hoped for 55% parts compatibility between the two planes, and eventually ended up with 0% compatibility. These prototypes were not delivered until February 1951. Performance of the new prototypes was "impressive," but they displayed unstable handling characteristics that demanded correction.[52]

The first production F-84Fs were not delivered to the Air Force until November 1952, and

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shortages of engines prevented completion of most of the aircraft. At one point Republic had over 450 completed airframes awaiting engines. To make things still worse, the first 375 aircraft had sub-standard, often defective engines, and were quickly dumped on the Air National Guard, who then retired them as quickly as they could. Not until 1955, with a new and more powerful engine, would the F-84F become an effective combat aircraft.[53]

The final production version of the straight-winged F-84 was the F-84G. The first F-84Gs were delivered in July 1951, and by the summer of 1952 enough of them were available to equip combat units in Korea. The F-84G was originally intended as an interim aircraft to bridge the gap between the F-84E and the new swept-wing F-84F. As it turned out, the F-84G was produced in considerably larger numbers than the armed version of the F-84F, and saw a great deal of action during the Korean War, alongside earlier F-84Es and a few F-84Ds. The F-84G incorporated a number of refinements that made it the most capable and effective of the straight-winged F-84s.

One of the most important changes in the F-84G was the introduction of the J35-A-29 engine. This engine provided an additional 600 pounds of thrust than was available from the J35-A-17 engine of the F-84E. Even with the extra thrust, the performance of the F-84G was virtually identical to the F-84E, demonstrating that the design had reached its aerodynamic limits. The extra power did allow the F-84G to carry heavier loads of external ordinance, which would prove an important asset during the Korean War. To accommodate the new engine's need for increased airflow, the F-84G was equipped with two small "blow in" doors on the lower fuselage beneath the cockpit. These doors would provide additional airflow when the aircraft was taxiing or at low airspeeds. Perhaps the most visible change in the F-84G was the addition of a new reinforced canopy, mentioned previously. This canopy proved to be very successful, and was therefore

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retrofitted to all surviving F-84 models.

Another innovation on the F-84G was the capacity for in-flight refueling. These aircraft had a small receptacle on the leading edge of the left wing, designed to accept a refueling boom from an Air Force air tanker. When not in use, this receptacle was covered by two triangular doors. This capacity would give the F-84G intercontinental range, although not under combat conditions. Later, to accommodate the alternate probe and drogue refueling system, F-84Gs also had small refueling probes added. Originally using just one, also on the outer edge of the left wing, later versions of the system used two, one on the front of each tip tank. Pumps would distribute the fuel to all the cells in the aircraft, giving it the capacity to completely refuel in the air. Another new modification with the opposite intent was a fuel dump system on the tip tanks, to allow a pilot to jettison excess fuel before a landing. To assist pilots facing long, boring flights in a cramped fighter cockpit, Republic installed a basic but functional autopilot in the F-84G.

Beginning with the 86th production machine, a new radar ranging gunsight, the A-4, was installed. From the 301st production machine, the F-84G was given a basic ILS (Instrument Landing System) to permit operations at night and in poor weather. The F-84G was also given the capacity to carry nuclear weapons, making it the first aircraft in the US Air Force other than large strategic bombers with the ability to deliver a nuclear device. The left bomb pylon was lengthened and reinforced, and extra electrical systems necessary to arm the weapon were also installed. This capability gave the Air Force greater flexibility in its nuclear capacity, although it must have been a daunting prospect for the pilot of a single-engined jet fighter to contemplate surviving dropping a multi-megaton bomb from his plane.[54]

Deployment of the F-84 prior to the Korean War was relatively limited. Only a few

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domestically based fighter groups or wings were equipped with the F-84 prior to the hostilities in Korea. No overseas units received the F-84 prior to the Korean War. This was due in part to the delays in the delivery of the F-84 and the host of problems encountered, but was also influenced, especially in the Pacific, by the F-84's extremely long take off run and the shortage of runways of sufficient length. (F-84 pilots swore that the plane contained a secret device called the "sniffer" deep inside, which would allow the plane to leave the ground only when it sensed the presence of dirt, and hence, the end of the runway.) A brief survey of those units which received the F-84 prior to the Korean War follows.

The first unit to receive the F-84 was the 14th Fighter Group. This group was part of Air Defense Command, ADC, and was stationed at Dow Air Force Base in Maine. They received F-84Bs beginning in December 1947.[55] The planes were a constant source of trouble, and the unit was never able to obtain operational status with the aircraft. The 14th FG was officially inactivated on 2 October 1949, due to budget cuts. Those F-84Bs still with the unit were either shipped back to Republic for remanufacture, or were dumped on an unsuspecting Air National Guard. The ANG, initially delighted to get such a modern fighter, quickly recognized the problems with the plane, and most of the early model F-84s that were given to the ANG were either remanufactured or retired within a few years.[56]

The second unit to receive the new F-84 was the 20th Fighter Bomber Wing, which was under the command of Tactical Air Command, TAC. The 20th FBW was stationed at Shaw AFB in South Carolina. The 20th, as discussed in General Quesada's letter, had considerable difficulties with the early models of the F-84. In February 1948, the 20th FBW received P-84Bs. They were never able to achieve full operational status with this model of the aircraft. In May

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1949, the unit traded their F-84Bs for F-84Ds. The F-84Bs were either returned to the factory or foisted on the ANG. The D model still proved troublesome, and eventually in November 1951, the 20th received F-84Gs. Squadrons of the 20th, with their F-84Gs, were among the first to practice both aerial refueling and the delivery of nuclear weapons.[57]

In the summer of 1948, two more units were equipped with the latest model of the F-84, the F-84C. These were the 33rd Fighter Wing, originally part of SAC but later transferred to ADC, and the 31st Fighter Group, under the command of TAC. The 33rd converted to the F-86A in the spring of 1950, while in July 1950 the 31st was transferred to SAC, to become the 31st Fighter Escort Wing. The use of F-84s as escorts for SAC's bombers was something of a desperation move, as several of those bombers, especially the B-45 and B-47, were actually faster than the F-84 at high altitudes. The 31st was then reequipped with the F-84E and transferred to Europe to participate in tests and maneuvers. The 31st would eventually be equipped with F-84Gs, and would also practice extended range formation flying and aerial refueling.[58]

The 78th Fighter Wing, part of ADC, received F-84Ds in February 1949. The 78th's experiences with the F-84 were among the worst of any unit in the Air Force. They had serious and constant problems with the aircraft, with frequent accidents and fatalities, and extremely low readiness ratings. In 1951, two of the three squadrons in the wing converted to the F-89 all-weather interceptor, and the third squadron converted to the F-94 all-weather interceptor in 1953.[59]

Finally, the 27th Fighter Escort Wing received the F-84E in February 1950, and the F-84G in July 1951. As these models had most of the bugs worked out, the 27th's experiences with the F-84 were less troublesome than the units that received earlier versions of the plane.[60]

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Several special programs involved the F-84 as test subjects or as major components. Two of these have already been mentioned - the in-flight refueling techniques and the ability to deliver nuclear weapons. The F-84, specifically the F-84G, was the first production fighter aircraft in the world to be able to perform either of these tasks, which made the F-84G a very versatile and useful aircraft for the Air Force. Several other experimental programs utilized the F-84 as a test subject, and these will be outlined briefly.

Most of these projects relate to one of the major weaknesses of early jet fighters - their extremely short range. The F-84, with its ability to carry both tip tanks and drop tanks, had better range than almost any other jet fighter of its day, but was still woefully short-legged compared to bombers or even some piston-engined fighters.

The first of these programs to extend the tactical range of jet fighters was Project Tip Tow. Derived from concepts conceived by German engineers during World War II, this project explored the idea of joining a fighter plane to a larger mother ship at the wing tip. The fighter could then be towed to its destination. The concept was similar to the parasite fighter program, but it proved to be much easier, due to lesser turbulence, to join aircraft at the wingtips, rather than putting the nose of the smaller into the belly of the larger. Hundreds of hookups were done to test this idea, with various types of aircraft, including the F-84, used as test subjects. Ultimately the project was dropped in favor of its successor, Project Tom Tom.

Tom Tom was similar to Tip Tow, except that in this case, *two* fighters would be attached to the bomber, one at each wing tip. This concept was tested with a B-29 and two F-84Ds. Again, the actual attachment, although not simple, proved relatively easy compared to the problems encountered by the parasite fighter program. In addition, the lift provided by the

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attached fighter's wings compensated for the extra drag they imposed, and the bomber did not suffer any noticeable performance loss. It was theorized that the bomber might actually increase its range with fighters on the wingtips. The fighters could shut down and restart their engines with no difficulty, using the airflow to turn the compressor. This allowed them to conserve fuel during a long flight.

The major problem with the idea was that the attached fighters remained vulnerable to external forces. In other words, they were subject to pitch, roll and yaw just like any other aircraft. However, since they were immobile on one wing tip, these forces could do unpleasant things to the aircraft. It was quickly learned that if the wing of the bomber started to oscillate, the attached fighter must be jettisoned immediately, or severe damage could result. The program suffered a temporary shutdown when the left F-84 rolled completely over and slammed into the wing of the B-29. Both aircraft crashed, killing all aboard.

The program was revived some time later, using F-84Fs and a B-36. Although a means had been found to compensate for some of the control problems, they could not all be contained, and the same type of accident nearly claimed all of the subsequent test aircraft. After this, the Tom Tom project was discontinued in favor of FICON.[61]

FICON (Fighter Conveyor) was in some ways a revival of the earlier parasite fighter program. The intent was to hook an F-84 to the undersides of a B-36. This was an outgrowth of earlier attempts to develop a workable parasite fighter, including the XF-85 and attempts to tow both the P-59 and P-80 behind a bomber. The hookup mechanism for FICON was similar to, if larger than, the equipment which had been designed for the tiny XF-85 Goblin. The concept was for the bomber to bring its own fighter escort along with it, releasing it when needed, and then

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having the fighter hook back up when it was finished destroying its opponents.

The concept proved technically feasible, if only just. The high level of skill demanded to perform the hookup, especially from the fighter pilot, made it a difficult concept to implement on a large scale. The use of the straight-winged versions of the F-84 in such a role never advanced beyond the testing stage, but a later development did see limited use. In order to obtain tactical photographic information from distant targets, the swept wing reconnaissance version of the F-84, the RF-84F, was used in the parasite role, attached to a B-36 mother ship. The B-36 would deliver the RF-84F near its intended target, and then the fighter plane would drop free and perform a high speed photographic pass, returning to the mother ship for the long voyage home. This concept was used operationally, although only for a few years. It was simply too difficult and hazardous for the fighter pilot to be a practical solution. And with such new aircraft as the Lockheed U-2 Dragon Lady spy plane becoming available, it was no longer necessary.[62]

One final experimental F-84 project was ZELMAL (Zero Length Launch and Mat Landing). This concept was similar to the takeoff and landing procedures used by the World War II German jet planes, such as the Me 163 and Ar 234, which took off on jettisonable wheeled trolleys and landed on skids. ZELMAL, however, had a much more ambitious goal - to allow jet fighters to take off and land without any airfield at all!

The takeoff was to be accomplished using an external jettisonable rocket motor - a king-sized version of JATO. The fighter would be mounted on an inclined ramp, would run the engine up to full power, and then ignite the rocket. The takeoff part of the project, in fact, went quite well. All the takeoffs were successful and uneventful. Pilots described the takeoffs as "very nice." Initially, after testing the takeoff, the planes landed conventionally. Eventually, the second

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portion of the program - the "Mat Landing" - was tested. This was not nearly as successful as the first portion. It was, in fact, a disaster.

With the Mat Landing, a large inflatable and lubricated rubber mat (400 feet long, 40 feet wide, 30 inches high) would be positioned. This mat had numerous separate cells, and an arrestor wire at one end. The fighter was equipped with an arrestor hook. The concept was sort of an inflatable land-based aircraft carrier, only it proved to be a good deal less durable. The first attempt to land on the mat was a catastrophe. The F-84 missed the arrestor wire, and the hook shredded several of the inflatable cells. The plane crashed, and was totally wrecked. The pilot sustained serious but recoverable injuries. The next two mat landing attempts were technically successful, in that the aircraft succeeded in catching the arrestor wire, but the results of the landings differed only in severity from the first attempt. The planes were badly damaged, and the pilots received severe whiplash from the abrupt "crash" landings. The Air Force had planned thirty test landings, but gave up after only three. England's Royal Air Force, which can be credited (blamed?) with devising this concept, had obtained similar results in tests. Some time later, the US Navy, either without access to the results of the Air Force's tests or not believing them, attempted similar tests using F9F Panther jet fighters. Results and conclusions were similar to the Air Force and RAF tests. The fulfillment of the concept of VERTOL (Vertical Take Off and Landing) would have to wait several decades for the Hawker Harrier jump jet.[63]

Perhaps this chapter has created the impression that the F-84 was a worthless airplane, an early example of the excesses and failures of the Military-Industrial Complex. While early versions of the F-84 were indeed unacceptable as combat aircraft, the blame for this was primarily the attempt to demand too much from limited means. The persistence of Republic, and the

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patience of the Air Force, were eventually rewarded with the introduction of the F-84G fighter bomber and F-84F interceptor. Both were highly successful aircraft, if not on the cutting edge of aviation performance. The F-84E and F-84G, in particular, would have enormously successful combat careers in Korea, performing more ground attack missions than any other fighter in the war.

One fact alone illustrates just how complete was the transformation of the F-84 from ruptured duck to graceful swan. After having many local, unofficial acrobatic flying teams during its history, in 1953 the United States Air Force finally created a single official Air Force acrobatic and precision flying demonstration air team, the Thunderbirds. For their demanding routines, the Thunderbirds needed an outstanding fighter plane, agile and maneuverable yet stable and dependable. The plane they chose as their first official mount? The Republic F-84G Thunderjet.[64]

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2. Wooldridge, ***The P-80,*** pp. 64-6.

3. Kinzey, ***F-84 Thunderjet***, pp. 12-3.

4. Aircraft Project Section, Engineering Division, to Republic Aviation Corporation, 3 May 1946, ***F-84 Case History***.

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6. Aircraft Section, Procurement Division to Research and Engineering Division, Assistant Chief of Air Staff - 4, 20 June 1946, ***F-84 Case History***.

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13. Colonel George Schaetzel, Chief, Aircraft Section, Procurement Division to Commanding General, Air Defense Command, Mitchel Field, New York, 3 December 1947, ***F-84 Case History***.

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19. Colonel M. E. Glaser, Deputy Chief, Maintenance and Supply Division, Assistant Chief of Air Staff - 4, Washington to Commanding General, Air Material Command, 22 September 1947, ***F-84 Case History***.

20. Lt. Gen. E. P. Quesada, Commanding General, TAC, Langley Air Force Base, Hampton, Virginia to Chief of Staff, United States Air Force, 16 June 1948, ***F-84 Case History***.

21. Colonel M. E. Glaser, Deputy Chief, Maintenance and Supply Division, Assistant Chief of Air Staff - 4, Washington to Commanding General, Air Material Command, 22 September 1947, ***F-84 Case History***.

22. Brigadier General Thomas S. Power, Chief, Requirements Division, Directorate of Training and Requirements, Washington to General Partridge, 24 May 1948, ***F-84 Case History***.

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25. Commanding General, Air Proving Ground to P-84 Project Officer, Aircraft Procurement Section, Engineering Division, 4 May 1948, ***F-84 Case History***.

26. McLaren, ***Republic F-84***, p. 186.

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28. Ibid., pp. 184-5.

29. Lopez, ***Fighter Pilot's Heaven***, p. 156.

30. Memo from Brigadier General Thomas S. Power, Chief, Requirements Division, Directorate of Training and Requirements, Washington to General Partridge, 24 May 1948, ***F-84 Case History***.

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33. McLaren, ***Republic F-84***, p. 33.

34. Record and Routing Sheet from Colonel George R. Schaetzel, Chief, Aircraft and Missiles Section, Procurement Division to General Shepard, Procurement Division, 26 February 1948, ***F-84 Case History***.

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40. Lieutenant General B. W. Chidlaw, Deputy Commanding General, Air Material Command to General E. R. Quesada, Commanding General, Tactical Air Command, 19 July 1948, ***F-84 Case History***.

41. Memo from Brigadier General D. B. Putt, Director of Research and Development, Deputy Chief of Staff, Material, Washington to Deputy Chief of Staff, Material, Washington, 4 October 1948, ***F-84 Case History***.

42. Air Staff Summary Sheet, October 1948, ***F-84 Case History***.

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47. Memo from Vice Chief of Staff, Washington to Undersecretary of the Air Force, 19 September 1949, ***F-84 Case History***.

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56. McLaren, ***Republic F-84***, pp. 36-8.

57. Ibid., pp. 46-50.

58. Ibid., pp. 38-9, 50, 58-63.

59. Ibid., pp. 39-44.

60. Ibid., pp. 56-9.

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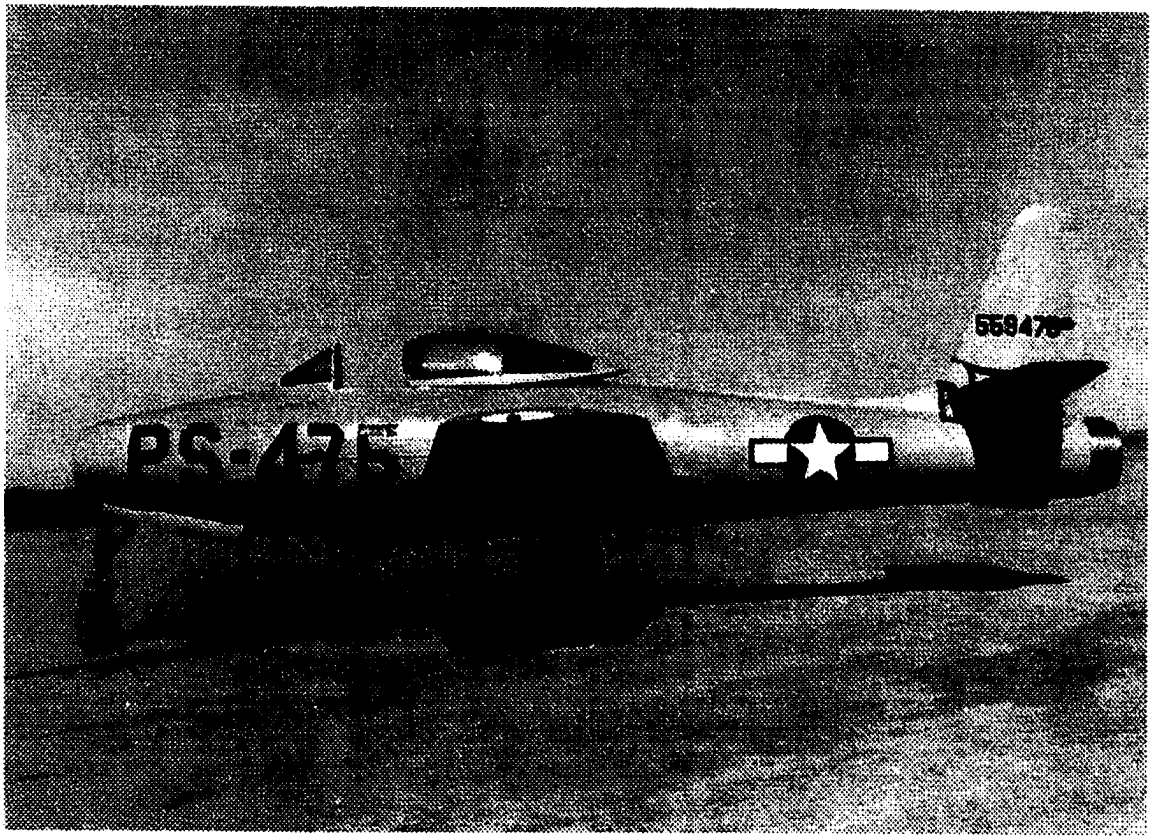
64. Kinzey, ***F-84 Thunderjet***, p. 51.

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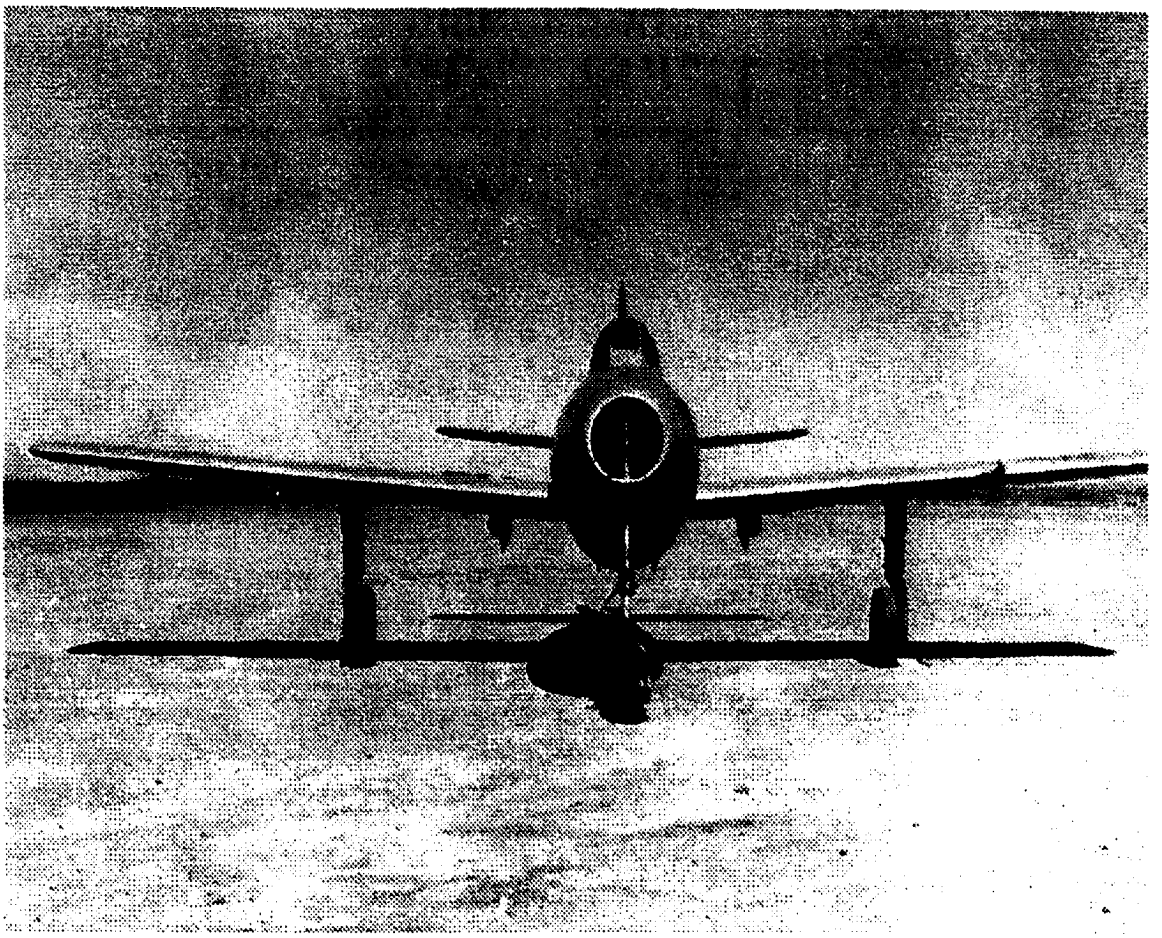
The first XP-84, undergoing tests at Muroc. Note the lack of armament and the overall gray paint scheme, used only on the three prototypes. The black lines on the tail are sealer over cracks in the paint. The large number on the nose is the "Buzz Number". This number is repeated under the left wing. The purpose of this number was to allow people on the ground to report an aircraft which was "buzzing", that is, flying very low and very fast. Photo credited to Wright Field, dated 19 March 1946. (National Archives, Photographic Division, Box 2031, Number 30309)

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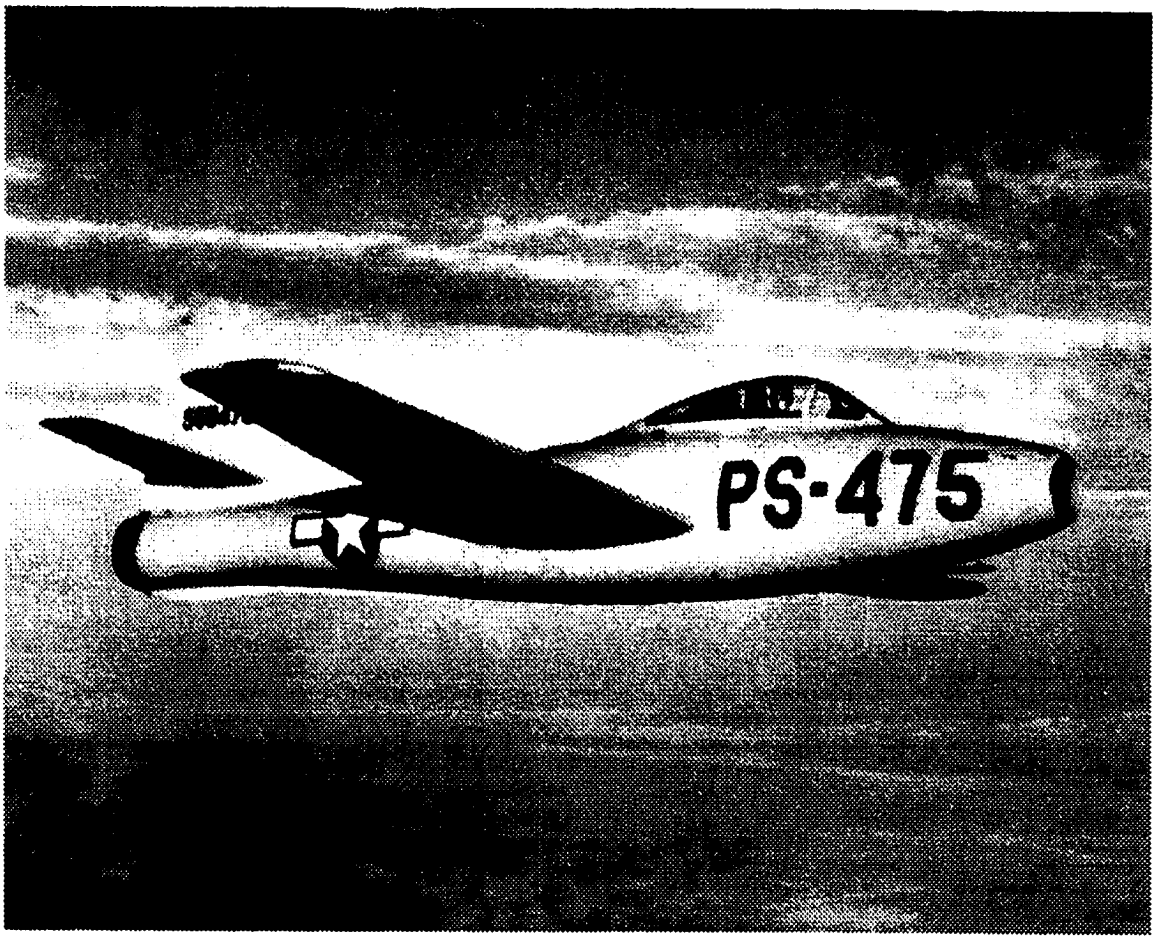
The same XP-84 from the side. The clean and slender lines of the aircraft can easily be seen in this photo. Note how the fuselage tapers behind the cockpit. Photo credited to Wright Field, dated 19 March 1946. (National Archives, Photographic Division, Box 2031, Number 30310)

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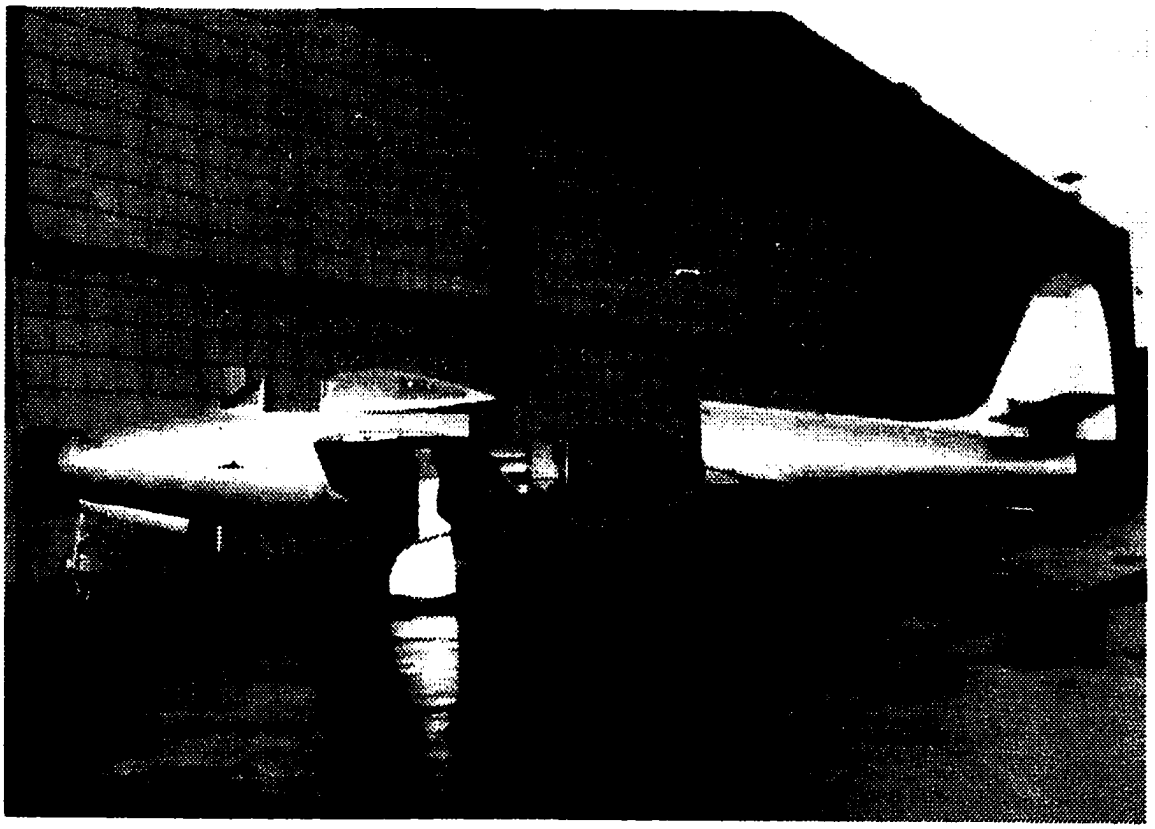
The XP-84 from the front. Again, the clean lines are obvious. Note the lack of tip tanks or even attachment points for them. Photo credited to Wright Field, dated 19 March 1946. (National Archives, Photographic Division, Box 2031, Number 30312)

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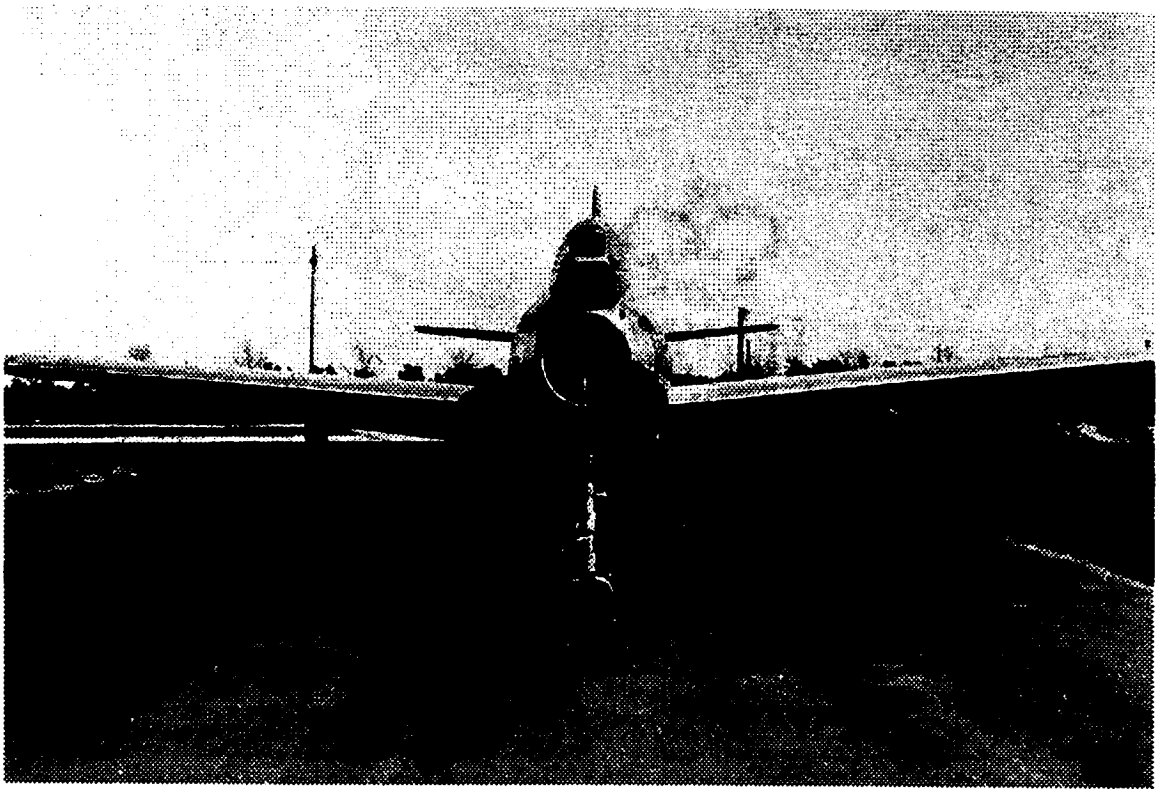
The XP-84 in flight. Note the small fin on the lower rear of the fuselage. This fin served both to add stability in flight and to act as a tail bumper on takeoffs and landings. Photo credited to Air Force Office of Public Relations, dated 14 August 1946. (National Archives, Photographic Division, Box 2031, Number 30315)

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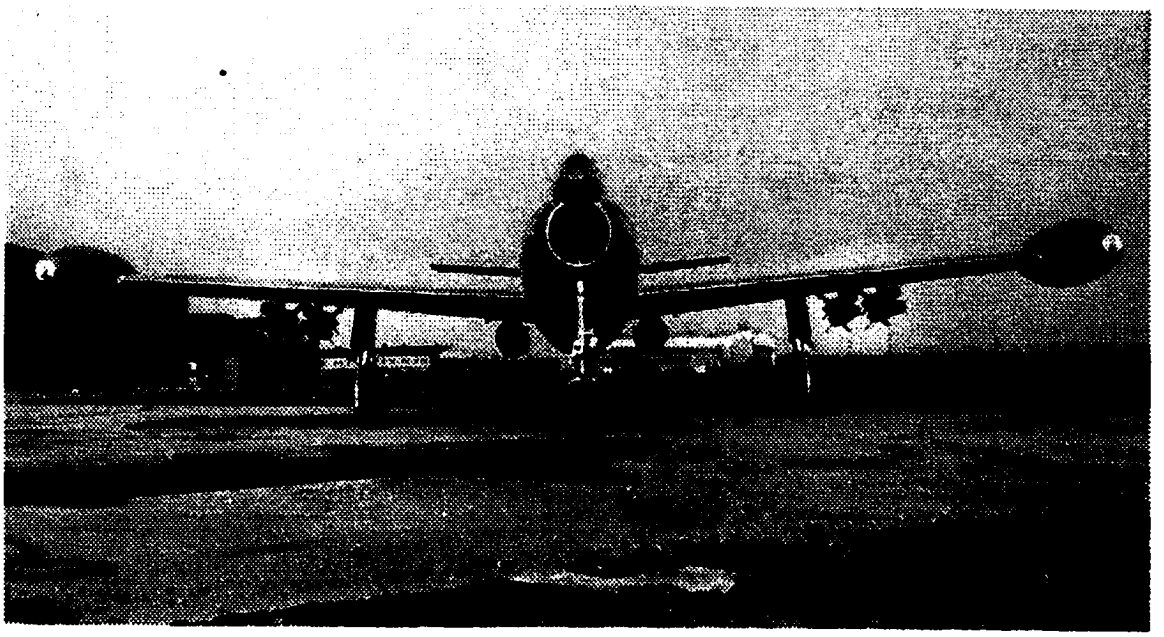
An XP-84 with the rear fuselage removed to show the engine installation. Note how low the engine actually sits in the fuselage, dictated by the need to route the airflow underneath the cockpit. Also note the special cradle supporting the rear fuselage portion. The gray paint has not yet been applied to this aircraft. The original caption reads "Engine Replacement - 20 minutes", a bit of fantasy that can only be excused by the fact that the plane was brand new and no one had actually tried to replace the engine yet. Photo credited to Air Force Office of Public Relations, dated 20 September 1946. (National Archives, Photographic Division, Box 2031, Number 30320)

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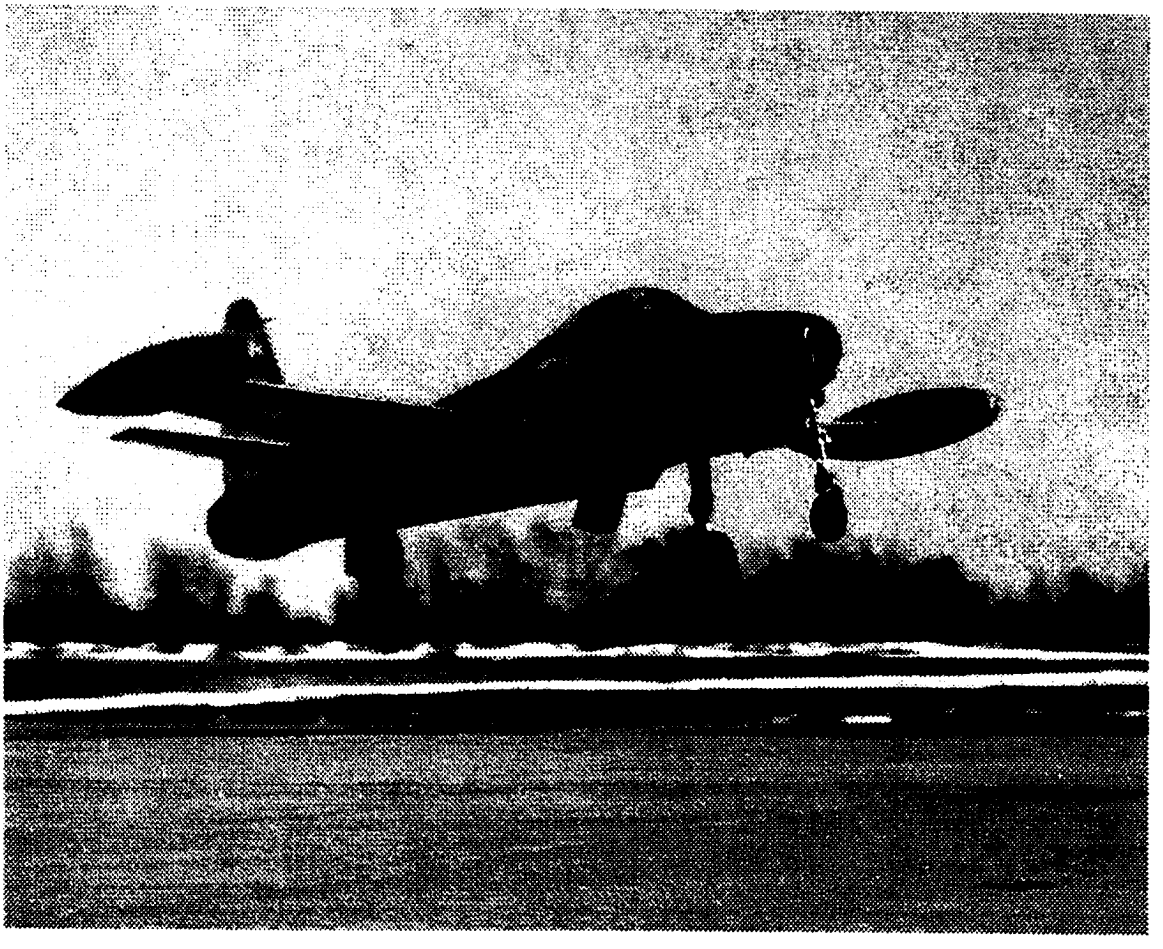
An early P-84 viewed from head-on. The vertical line in the center of the nose air intake is the splitter, which was a divider that seperated the airflow into two passages. (National Archives, Photographic Division, Box 2031, Number 30276)

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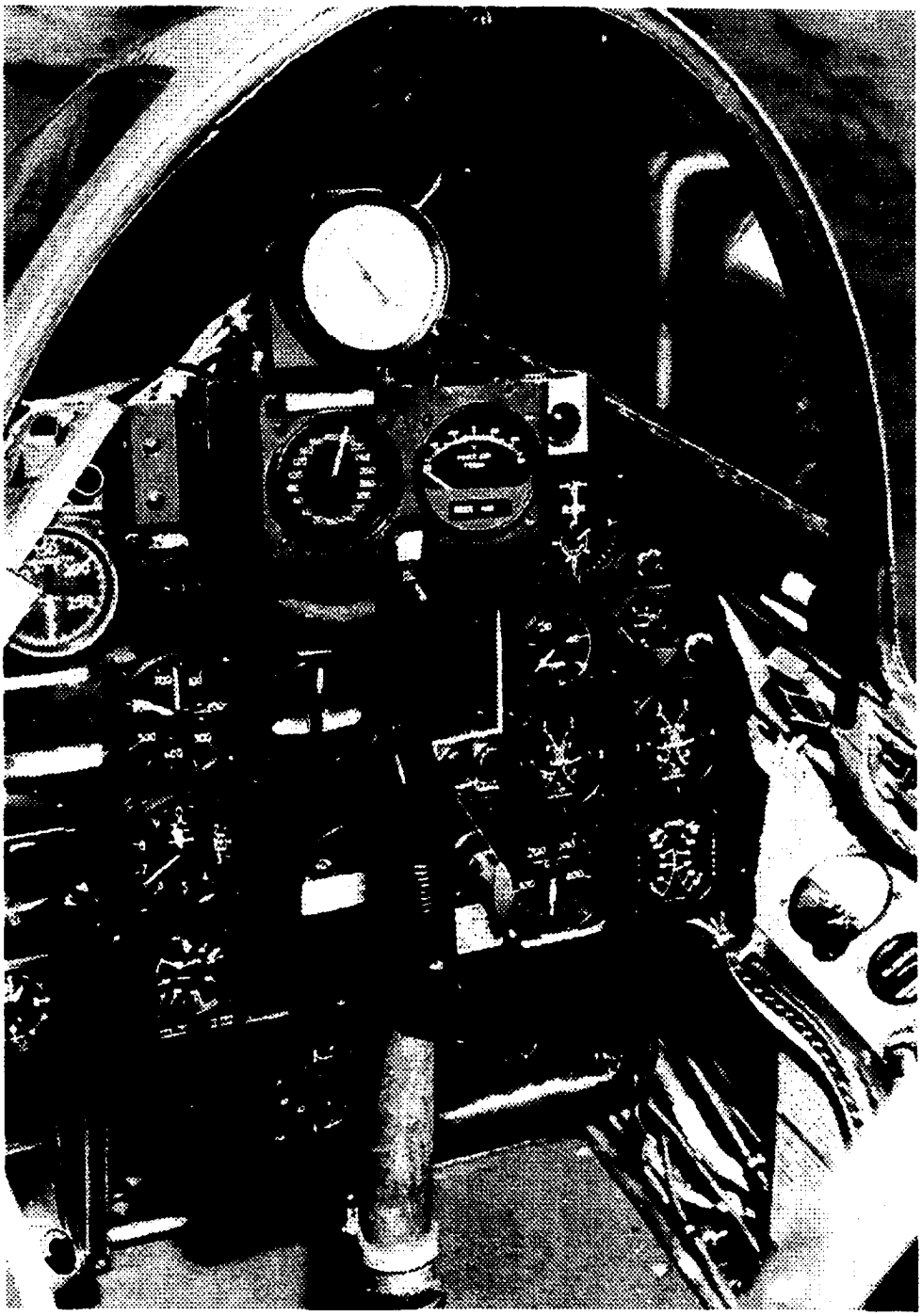
An F-84 equipped with eight 5" HVAR rockets and two 500 pound bombs. All of these weapons are mounted on the original short retractable mounts, which were eventually replaced with longer, detachable mounts. Photo credited to Republic Aviation Corporation, dated 26 April 1949. (National Archives, Photographic Division, Box 2031, Number 30297)

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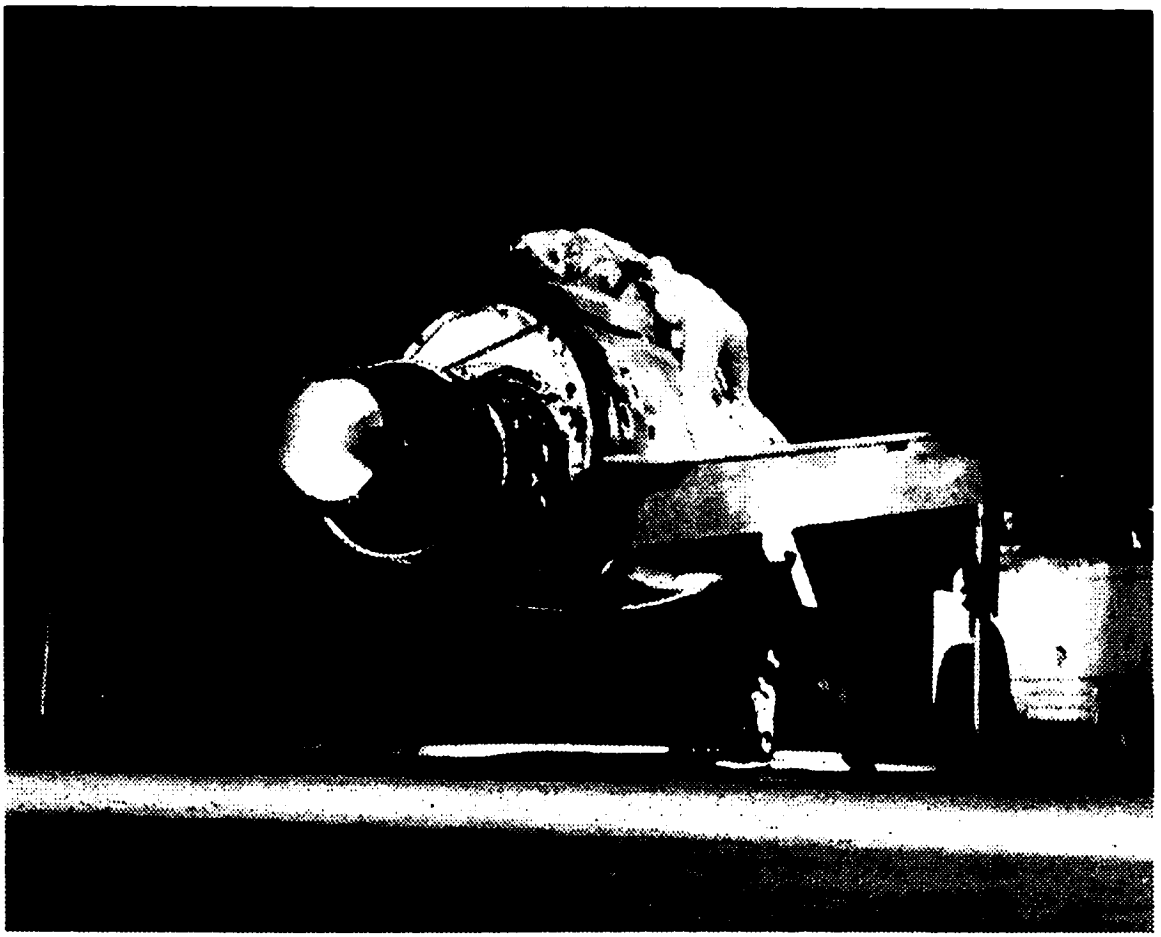
An F-84B of the 14th Fighter Wing, coming in for a landing at Dow Air Force Base in Bangor, Maine. Note the deployed air brake on the lower side of the fuselage, and the gap in the landing gear covers. The landing gear used a compression strut to help support the weight of the aircraft, and when the weight was not on the gear, they extended beyond their normal length. A retractor mechanism was then used to contract the gear to enable it to fit into the wheel wells. Photo credited to James Evans, dated 15 March 1948. (National Archives, Photographic Division, Box 2031, Number 30299)

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The business office of an F-84B. The basic nature of the early jet fighters can be seen in this photo. Photo dated 9 April 1947. (National Archives, Photographic Division, Box 2031, Number 30300)

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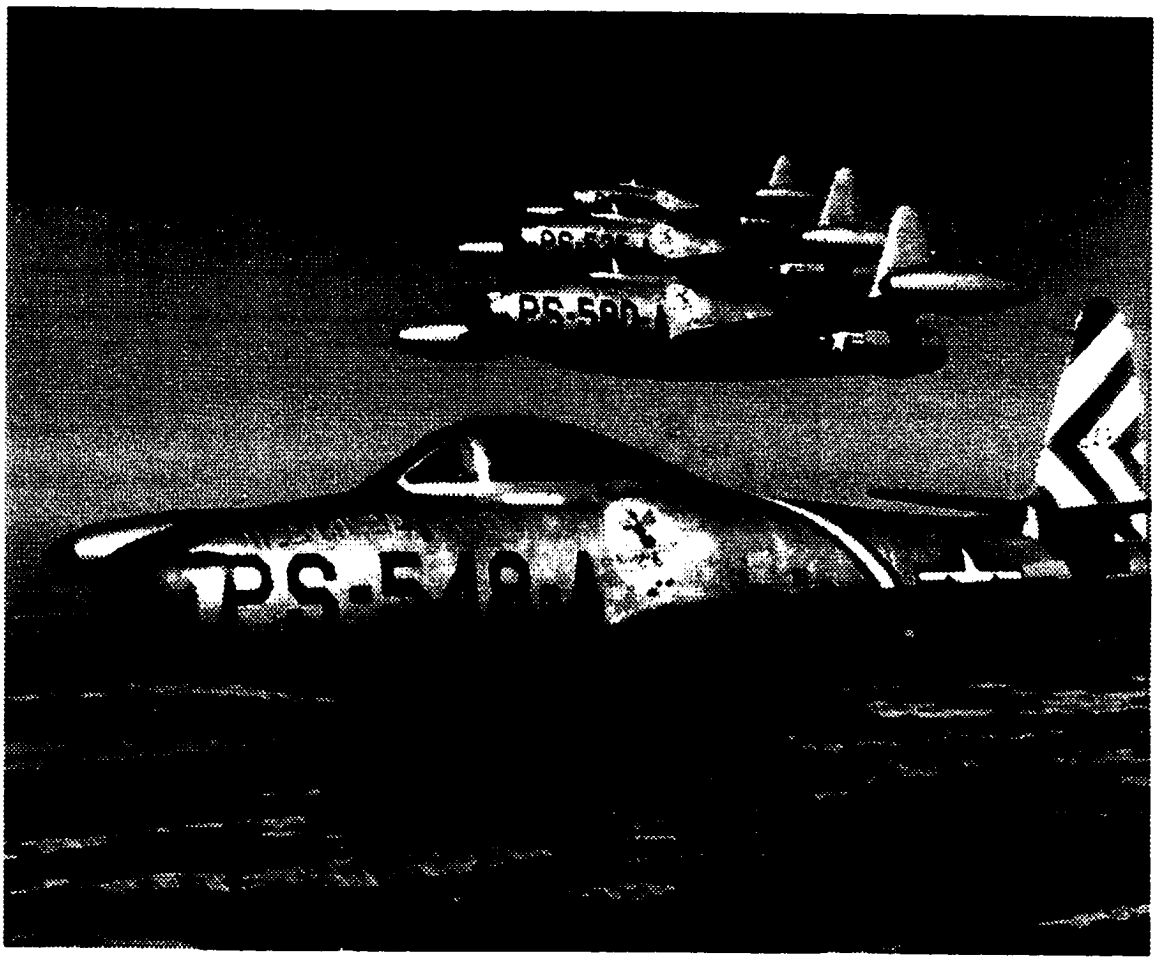
An F-84 with the tail section removed, running the engine at night. This was part of a pre-flight check. The aircraft is part of the 33rd Fighter Wing at Otis Air Force Base at Falmouth, Massachusetts. Photo taken 1 November 1949. (National Archives, Photographic Division, Box 2031, Number 30305)

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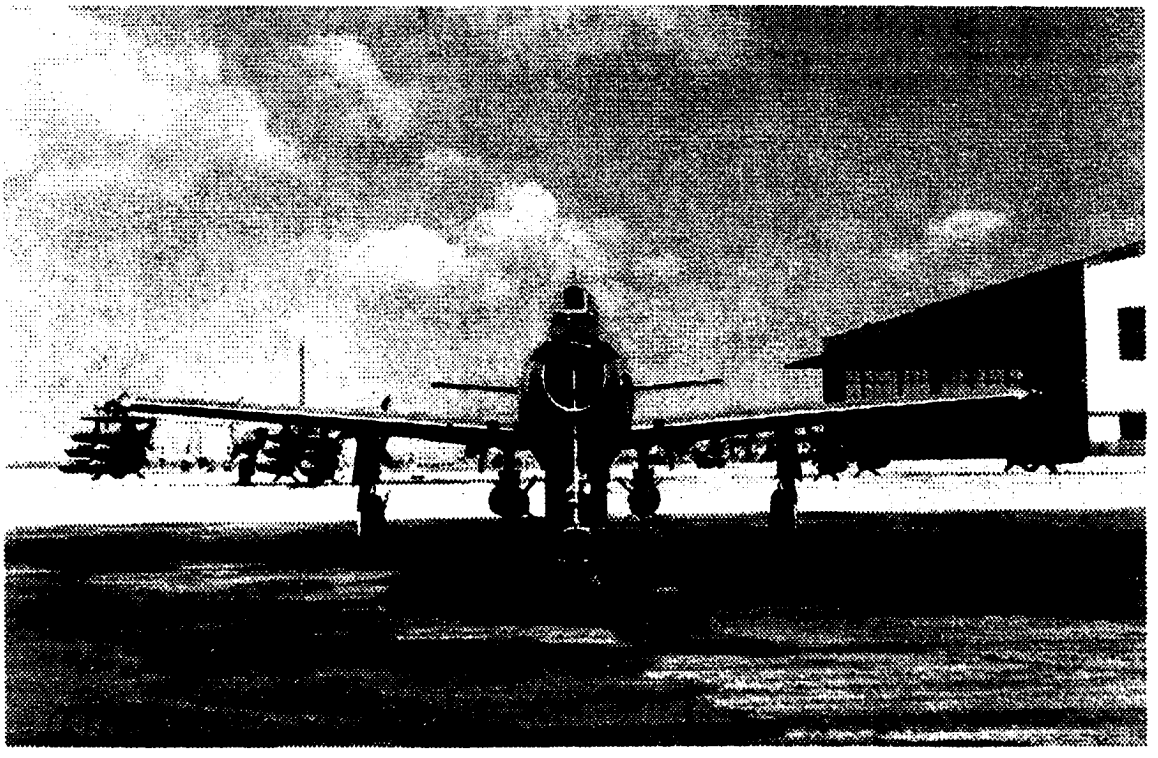
A publicity photo of a pair of P-84Bs on a shakedown flight prior to delivery to the 20th Fighter Group. Photo dated 25 April 1949. (National Archives, Photographic Division, Box 2031, Number 30332)

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P-84Bs of the 14th Fighter Group, at Dow Air Force Base, Bangor, Maine. The plane nearest the camera, "Itsy Bitsy", was flown by Lieutenant Colonel George Lavin, Jr., commanding officer of the 49th Fighter Squadron. Photo credited to James Evans, dated 15 March 1948. (National Archives, Photographic Division, Box 2031, Number 30336)

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An F-84E loaded for bear. The tip tanks have been removed, and rocket launcher stubs hung in their place. The plane is carrying a total of twenty four 5" HVAR rockets. Hung on the longer pylons near the fuselage are two of the immense 11" Tiny Tim rockets. Although experiments were conducted with armaments packages like this one, in actual operations F-84s were limited to no more than two rockets per stub instead of the three per stub pictured here. Photo credited to Eglin Air Force Base, Florida, dated 17 November 1953. (National Archives, Photographic Division, Box 2031, Number 30396)

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An F-84G of the 49th Fighter Bomber Wing. According to the original caption, the plane was enroute from Japan to Bangkok, Thailand. Several features of the G model are noticable in this shot. The reinforced banded canopy is obvious, and the aerial refueling probes can be seen on the front of the tip tanks. Close examination will also reveal the triangular doors covering the wing mounted refueling recepticle just out from the fuselage. Not visible in the shadows below the "33" on the fuselage is the "blow in" door for the extra engine airflow. Photo dated 7 December 1953. (National Archives, Photographic Division, Box 2031, Number 30449)

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THE DEVELOPMENT OF UNITED STATES AIR FORCE FIRST GENERATION JET FIGHTER AIRCRAFT, 1941-1950

by

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Volume II

A dissertation submitted to the Graduate Faculty in History in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2001

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"The Sabre represented the crossroads of the old and the new. It had in full measure the flying qualities of the best propeller machines. At the same time it gave all the excitement of the dawn of a new era - swept wings. It was exciting, and somehow a joyous machine and that is why it is remembered with so much affection."
RAF pilot George Bailey describing his feelings about flying the F-86[1]

Chapter 9
The Shape of the Future: The Development of the F-86

When World War II ended, the XP-86 was just a drawing board concept - a literal paper airplane. This concept was the result of North American Aviation's efforts to interest the US Navy in a new fighter plane. When the Navy expressed an interest in a prototype jet fighter, North American responded with the a design that would become the FJ-1 Fury. The Fury was thoroughly conventional by current American standards, with a sturdy tubular fuselage, straight wings, and tricycle landing gear. Many elements of the design were simply borrowed from North American's immensely successful P-51 Mustang. The Fury prototype was then modified to attempt to meet Air Force requirements for a new jet fighter. The fuselage was slimmed down, and the entire airframe was lightened, resulting in the original XP-86.

Although the Air Force approved a partial mockup of the original XP-86, North American's studies indicated that the XP-86 would possess only a small performance advantage over the P-80, and would likely be inferior to it's main competitor, Republic's XP-84. It was realized by the company that such an aircraft would be very unlikely to be selected for production by the Air Force. The primary limitation was speed. The Air Force wanted a 600+ mph fighter, and the power limitations of the available jet engines seemed to argue that this was unlikely. So North American began to search for a means to increase the speed of their planned prototype.

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About this time captured German research was becoming available in the United States. During the 1930s and early 1940s Germany had been home to many of the world's best scientists, researchers and engineers. As the war wound down, the American government's Operation Paper Clip oversaw large-scale efforts to bring this knowledge, and where possible, the individuals who had created it, back to America. Watson's Whizzers (or more formally the 54th and 56th Air Disarmament Squadrons), under the command of Colonel Harold Watson, was specifically tasked with obtaining German aircraft and technical documents relating to them. The Whizzers were responsible for bringing dozens of the latest German aircraft to America for evaluation. This would give companies such as North American access to materials and data that would have taken them years to assemble on their own.[2]

North American began to focus, in particular, on studies done by Messerschmitt AG for the creation of more advanced versions of their deadly Me 262 *Schwalbe* jet fighter. This new version would have had larger, more powerful engines buried in the wing roots, and a sharper sweep back to the wings.[3] Although this new version had not even achieved prototype status when the war ended, extensive wind tunnel tests had been done on models of it. The results of these tests would prove to be of immense value in helping North American study the concept of wing sweep.

The potential advantage of using swept wings to delay the onset of compressibility had been known for some time. What was also known was that swept wings also decreased lift and stability at low speeds. It would be of little use to develop a plane that could travel extremely fast if it was so unstable it could not take-off or land. The limited American experience with swept wing aircraft, especially the Curtiss XP-55 Ascender, had been very negative. Once again, the

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German tests and equipment would provide the answer - automatic leading edge slats.

Leading edge slats were portions of the leading edge of the wing that, under certain conditions would move forward and angle downward, creating a different shape to the front of the wing. This altered shape would greatly increase the lift and stability of the wing. German aircraft designers had been using slats on the wings of their planes since the mid-1930s, although no other country seems to have adopted the practice until after the Second World War. The chief problem with the slats was not their effect, but their operation. It was difficult to ensure that the slats deployed when they were needed, and not otherwise. A related problem was making sure that both slats deployed at the same time. Having only one deploy was almost worse than having neither of them do so, for it would create an asymmetrical lift situation. German aircraft designers had experienced problems with the slats on their airplanes, but had been able to correct the worst of them.

Once a few North American engineers had obtained the necessary mastery of technical German, so that the documents themselves could be examined, it was plain to the design team at North American that the combination of swept wings with leading edge slats offered tremendous possibilities for obtaining higher speeds from a given amount of engine power. On 14 August 1945, North American received a government grant to study the effects of wing sweep on their XP-86 design. They first built a scale model for wind tunnel tests. This model used a 35 degree sweep. The slats were modeled by removable pieces of metal that duplicated the shape of the slats when deployed.[4]

Wind tunnel tests on the wing models, begun 18 September 1945, confirmed North American's hopes. Without the slats, the swept wings allowed for higher speeds and smoother

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handling at those high speeds, with the slats deployed, the wings offered acceptable low speed handling characteristics. The results of these tests prompted the Air Force to grant North American approval to modify their XP-86 to a swept wing configuration.

The modification of the XP-86 delayed the project considerably. The first prototype XP-86 would not take to the air until 1 October 1947, almost two years after the first swept-wing tests. The process of creating this new version was a long and often difficult one. The design of the slats, in particular, proved troublesome. Eventually, an entire Me 262 wing was flown to Wright Field, where it was disassembled for study. Several components of the original XP-86 wing slats, including the tracks for attachment points, the lock, and the control switch were in fact simply taken from the Me 262 wing and modified to fit the XP-86 wing.[5]

The finished swept wing XP-86 bore little resemblance to the original straight winged version. Sleek and elegant, it exuded an air of speed and menace even when sitting on the ground. Not just the wings, but also the horizontal tail surfaces and the rudder had been swept back at the same 35 degree angle as well. The roughly cylindrical fuselage housed the engine, cockpit and armament. The cockpit, placed near the front of the fuselage, offered unmatched visibility from its bubble canopy. And unlike both the P-80 and P-84, the pilot could enter the cockpit without the use of special ladders, thanks to various hand and footholds built into the side of the fuselage.

The wings were the most novel element of the XP-86. The sweep back was the most obviously different feature of the wings, but they were also very thin, and employed a new and unique means of construction. The standard means of construction for wings was the so-called "rib and stringer" method. Using this technique, large "ribs" ran from the leading edge to the

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trailing edge of the wing. These ribs were cut to the cross section shape of the wing at that point, and then attached to each other by smaller pieces, the stringers. When a rib and stringer form was complete, the basic shape of the wing was present, even though the outer skin was missing. The outer skin was then simply attached to the overall wing form. With the earliest fabric covered planes, the outer skin was just that - a covering to smooth out the aerodynamics of the load-bearing rib and stringer interior. With the development of the stronger and yet very light aluminum, the use of the outer skin to support some of the plane's weight became common, leading to the "stressed skin" construction, which allowed a decrease in the number of internal supports needed.

The XP-86 took the stressed skin concept to its ultimate expression up to that point. Doing away with a substantial number of the internal ribs, the wing relied for much of its structural support instead on a double layer stressed outer skin. The two skin layers were separated by small "hat" sections, and the thickness of the skin panels was tapered - thicker at the wing root and thinner towards the tip. North American found it necessary to buy and install special milling machines in their factory, in order to produce the panels that were used in the wings. But these new double skinned wings proved to be very strong, and the space saved by eliminating much of the internal bracing was put to good use holding additional fuel cells.[6]

The XP-86 was also designed with three "speed" or "air" brakes - panels that would open into the airflow around the plane, to create drag and slow the aircraft. These were considered to be essential in an aircraft whose performance would bring it right up to the sound barrier and the resultant compressibility. Two were located on the sides of the rear fuselage, just forward of the tail, and the third on the underside of the fuselage, further forward, just behind the wing. On the

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first XP-86, the two fuselage-mounted air brakes were hinged on the rear, and opened towards the rear of the aircraft. This was quickly changed to forward hinged/opening brakes on the succeeding prototypes and all production models. Likewise, the air brake on the underside was deleted from all subsequent machines.[7]

The XP-86 was designed with a compartment in the nose, above the air intake, to house an APG-30 radar set that would feed its input into the gunsight, although the first production models used the older gyroscopic sights. The radar antenna was to be housed in a small "nose" above the air intake. The concept of a radar ranging gunsight was quite simple - the pilot simply "dialed in" the gunsight to the proper wingspan of the opposing aircraft (the MiG-15 was 33 feet) and then pointed the nose of the plane at the enemy, and closed range. When the target indicator light glowed, you were in range and on target, and could open fire. Of course, in combat situations it was rarely so simple, and there were numerous problems with the early models of the gunsight.[8]

Many pilots, especially the veterans of World War II, who were used to the older gyroscopic sights, simply turned the new radar sight off. Colonel Francis "Gabby" Gabreski, a 28 victory ace who had flown P-47 Thunderbolts with the Eighth Air Force, and who would add 6.5 additional victories flying F-86s in Korea as the commander of the 51st Fighter Interceptor Wing, was so disgusted with the performance of the sight that he claimed that anything, even chewing gum stuck to the windscreen, would be better. This, of course, gave rise to any number of jokes about "gum sights", and even the occasional story that a wad of gum was what Colonel Gabreski used for a sight. The initial A-1CM would eventually be replaced by the A-4 radar ranging sight, which used the same principle, but was easier to use and maintain. And significantly, the younger

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pilots, not having become used to the older sights, had little difficulty using the radar sights to good advantage.[9]

The intended armament of the P-86 was six .50 caliber Browning M3 machine guns, located in two bays, three guns in each bay, on each side of the fuselage outside of the cockpit. The guns would fire through ports near the nose of the plane. None of the three XP-86 prototypes was armed, however. Consideration was also given to the attachment of racks for carrying external fuel tanks, bombs or rockets. Again, none of the XP-86s carried these racks, although production machines were capable of carrying them.

Like the P-80 and P-84, the fuselage of the XP-86 was designed to break apart just aft of the wings, to allow easy access to the engine for maintenance and replacement. Again, a special cradle was designed to hold the rear fuselage section while work was being done on the engine. The production versions of the P-86 were intended to be powered with the J47-GE engine, which would produce about 5,000 pounds of thrust, but due to production delays, this engine was unavailable for the XP-86. The XP-86 was instead powered by a J35-A-5 engine, which produced only 3,920 pounds of thrust.[10]

The full-scale mockup of the swept-wing XP-86 was shown to the Air Force on 28 February 1946. The Air Force approved construction of the three XP-86 prototypes on 20 June 1946, after the results of the wind tunnel testing on full sized models were known. North American began construction of those prototypes in August 1946. Excited by the projected performance of the XP-86, on 20 December 1946 the Air Force gave a contract to North American for 33 production model machines.[11] For the second time, the Air Force was willing to order a brand new jet fighter without even knowing if it could fly. Unlike the problems

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experienced with the P-84 however, in the case of the P-86 this decision would prove to be a sound, or at least a lucky one.

On 8 August 1947, the first XP-86 emerged from North American's factory. After undergoing various Air Force inspections, and then a series of power, taxiing, and braking tests at Mines Field (now Los Angeles International Airport), which was adjacent to the North American factory, the XP-86 was shipped to Muroc for flight testing.[12] Finally, on 1 October 1947, the XP-86 was ready for its first flight. At the controls was North American's chief test pilot, George "Wheaties" Welch. Welch was not only a skilled pilot, but also a combat veteran of World War II. On 7 December 1941, Lieutenant Welch took off in his P-40B from Haliewa Field, a small secondary airstrip, and managed to shoot down four of the attacking Japanese planes. Awarded the Distinguished Flying Cross for his actions, Welch would go on to accumulate 16 kills during the war, before taking the test flying position with North American in 1944.

Welch powered up the XP-86 and headed down the runway. The plane gently lifted its nose and climbed into the sky. Intended to be a short familiarization flight, the first flight of the XP-86 would instead last almost an hour. After completing a gentle circuit around the airfield, Welch brought the plane in for a landing. When Welch attempted to land, the main gear of the XP-86 deployed, but the nose gear indicator light did not go on. Unable to see the gear for himself, Welch queried ground observers. They confirmed that the main wheels appeared fine, but that the nose wheel was only halfway down, dangling at a 45 degree angle. In a decision that put common sense and compassion above financial gain, the observers on the ground left the final decision to attempt a landing or abandon the plane to Welch. Welch chose to try to land the plane. Spending nearly an hour flying circuits of the field, Welch attempted to gently "rock" the

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plane to push the nose wheel down. Unsuccessful and running low on fuel, Welch decided to bring the plane in anyway.

Welch brought the plane in with the gentle skill of a master pilot, touching down on the two main wheels first. The shock of the main wheels touching down, combined with the lower airspeed, was finally enough to bring down the nose wheel, which swung down and locked into place just seconds before the weight of the plane came down on it. As the plane taxied in from the runway, Welch was heard quietly murmuring over and over on the radio "Lucky, Lucky!"[13]

The problem with the nose wheel was traced to a skeptical individual somewhere in the landing gear or hydraulics sections of the design process. This person was apparently not convinced that the data obtained by the wind tunnel testing was accurate, and substituted a hydraulic piston for the nose gear that was easy to obtain, rather than the more powerful one called for by the test results. Most previous American aircraft with nose wheels had retracted the nose wheel forward, so that when it deployed, the force of the airflow would help bring it down and lock it into place. But on the XP-86 the space requirements of the air intake duct and the armament bays precluded such an arrangement. The nose wheel on the XP-86 instead retracted to the rear, deploying forward, *against* the airflow. This called for much more power from the hydraulic system, and this was where the potentially lethal mixup had occurred.

The fix for this problem on the XP-86 was simple - use two cylinders instead of one. All subsequent machines used the stronger hydraulic system called for in the original design specifications, and there were no further problems with nose gear deployment. The nose wheel could occasionally collapse while the aircraft was on the ground, though, if the crew chief forgot to lock the wheel into place once the aircraft was parked.[14]

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Aside from this relatively minor but potentially serious problem, there were no difficulties with the XP-86's maiden flight. Once the nose gear was fixed, subsequent flights were trouble-free. The closest thing to a complaint that Welch had about the flight testing was that the XP-86 was underpowered. Since the engine that would power the production machines would have considerably more thrust, this was not considered a significant problem.

In almost all other respects, the XP-86 was a "pilot's dream." Stable in flight yet highly maneuverable, the XP-86 had few vices. It was responsive to the controls, well balanced, and gave ample warning of an impending stall. Even in a spin it handled well. To recover from a spin, (assuming he had sufficient altitude) the pilot simply took his hands and feet off the controls and let them neutralize. In fact, the F-86 was one of the few combat aircraft in which the pilot was allowed to deliberately enter a spin, because its recovery was so easy. Both the XP-80 and the XP-84 had had uneventful early test flights, leading to highly positive assessments of the planes. These assessments had later proved to be overly optimistic, especially in the case of the P-84. The F-86, on the other hand, proved to be every bit as good as the early test flights of the XP-86 had indicated.

While the Air Force was pleased with the excellent handling characteristics of the XP-86, what really excited them was the speeds which the prototype was capable of. This was especially true since the prototype had 20% less power than the production machines were going to have. Early speed tests had revealed that the XP-86 could obtain speeds of at least 650 mph. During some of these tests, Welch had complained of fluctuations in the airspeed and altitude gauges. From earlier experience, it was known that these fluctuations could be the result of transonic shock waves produced by nearing the mach limit.

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NACA had set up a testing site at Muroc as well, with equipment that could accurately measure the speed and mach number of an aircraft at any height above the facility. The North American representatives talked NACA into using their equipment to track the XP-86 during test flights. During dive tests on 21 November 1947, the XP-86 was measured at Mach 1.03! The sound barrier, Mach 1, had officially been broken by Chuck Yeager on 14 October 1947, while flying the rocket powered Bell XS-1. But Welch had been performing dive tests similar to the one that was measured at Mach 1.03 before that date, and so may well have beaten Yeager to this historic first. However, without the means to measure and record such an achievement, such feats remain in the realm of speculation.[15] [16]

The XP-86 however, was the first real airplane to officially break the sound barrier. The Bell XS-1 (later the X-1) was not really an airplane, but an air-launched manned rocket. Intended only for high speed test runs, it could not take off on its own, and had to be carried to altitude by a larger mother ship. The XP-86 was the first machine capable of taking off and landing on its own that officially exceeded Mach 1.

At that time, the speed of sound, often called the sound barrier, existed in many people's minds as sort of a giant invisible wall, against which an unwary plane would smash if it went too fast. As a result of this conception, as well as the supposed national security implications of exceeding the speed of sound, or 'breaking the sound barrier,' all those connected with the XP-86 program were sworn to top secrecy about the high-speed trials, although various pilots continued to break the barrier in secret. Finally, in the spring of 1948, a British exchange pilot flying the XP-86 accidentally broadcast his excitement about breaking Mach 1 over an open radio frequency, and the secret was out. In May 1948, it was publicly announced that George Welch

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had exceeded the sound barrier in the XP-86.[17]

After the completion of the Phase I flight testing, done by the manufacturer, the Air Force took over and conducted several other series of tests to determine performance limits, combat capability, and maintenance requirements. These tests were also conducted at Muroc, and the only significant problem was a failure of the cabin pressurization system during a high altitude test. This failure could have had serious repercussions, including the incapacitation or death of the pilot, but fortunately the oxygen system was able to sustain the pilot until he landed.

The performance of the XP-86 was such that on 16 October 1947, the Air Force not only ratified the original contract for 33 P-86A machines, it added another contract for an additional 190 P-86B airplanes.[18] Here at last was the world-beating jet fighter the Air Force had been hoping for for the last four years.

One of the more unusual aspects of the P-86 program was that there were no official YP-86 airplanes. The "Y" series of pre-production aircraft were usually used to test the final modifications to the prototype before the beginning of full-scale production. However, the Air Force was satisfied enough with the XP-86 testing that they saw no need for any additional YP-86 machines. The three XP-86 aircraft were eventually fitted with J47 engines in place of the J35 engines they had initially received. This engine uprating prompted a change in the prototype's data blocks (small lettering on the aircraft giving model and serial number and other manufacturer's information) from XP-86 to YF-86, but there was no official Air Force change of designation, and no official tests were ever assigned to YF-86s.[19]

The first of the initial production block of 33 P-86As rolled out of North American's factory on 15 May 1948. All of the initial batch of 33 P-86As, by that point officially designated

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as the P-86A-1 (later the F-86A-1), were used for various testing purposes. There were insufficient numbers of the P-86A-1 to equip a fighter group, so they were parceled out to North American, NACA, and various Air Force projects for tests. They were also used as transition training aircraft for units slated to receive the P-86, and small numbers of them would be sent to those units for that purpose.[20]

There were not many differences between the XP-86 and the P-86A-1. The most obvious difference was that the P-86A-1 was armed, both with the six internal machine guns and with the ability to carry external ordinance. The machine gun ammunition bays were designed to hold 300 rounds per gun, but the usual load was 267, to prevent jamming and other feed problems. The P-86A was also stressed to carry two bombs of up to 1,000 pounds, or sixteen 5" HVAR rockets, or two 206.5 gallon external fuel tanks.

The P-86A-1 also had the intended production engine. It was something of a first in the American jet fighter program for the very first production version of an airplane to be equipped with the engine it was designed to use, rather than have to make do with a less powerful engine because the intended engine was not yet available. The new engine was the J47-GE-1, rated at 4,850 pounds of thrust. This new engine increased the already high top speed of the P-86, to over 670 mph, and almost doubled it's climbing rate, from 4,100 feet per minute for the XP-86 to 7,800 feet per minute for the P-86A-1. And the service ceiling was increased from about 41,000 feet to over 46,000 feet.[21]

The speed of the P-86A-1 was so impressive that the Air Force determined to use one of these aircraft to set a new absolute speed record. The attempt would be made in front of the large crowds at the Cleveland National Air Races, over the Labor Day weekend, 4-6 September 1948.

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This was the first time that a speed record would be attempted before a substantial audience. F-86A-1 number 47-608, which had been used for cold weather trials, was to be used for the attempt.

A special circuit was set up for the speed trials, with the necessary number of precision cameras and measuring instruments. On the morning of 5 September 1948, Major Richard Johnson made six high-speed level passes through the course. Although Major Johnson averaged almost 670 mph on his six runs, problems with the recording equipment meant that only three of them were properly recorded. Since four runs were needed to create the necessary average, the attempt could not be used for an official record. Major Johnson was ready to try again the following day, but inclement weather prevented the flight.

Undeterred, the Air Force decided to try again, in a location where the weather would be less of a factor. With the same measuring equipment set up, the speed trials moved to Muroc, with the same pilot but a different aircraft, F-86A-1 number 47-611, used for armament tests. An important element of these speed trials was that the aircraft used was a standard production aircraft, with no special modifications, and had full military equipment, including self-sealing fuel tanks, armor, and all six machine guns.

On 15 September 1948 Major Johnson made the necessary six level passes in front of the measuring equipment, at altitudes below the 100 meter minimum altitude the standards required. All six runs were very close in speed to one another, with the slowest being 669.83 mph, and the fastest being 672.76 mph. The average of the runs, 670.78 mph, was the new absolute speed record, and would stand for four years, until broken by another F-86, the after-burning F-86D.[22]

One special characteristic of the P-86A-1 and an indeterminate number of the later A-5

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version was the use of small doors covering the gunports in the nose. The machine guns on the P-86, did not protrude from the outer skin of the plane, as had been the usual practice with previous American Air Force fighters. Rather, the gun barrels connected to blast tubes, which in turn ended just below the outer skin of the plane. A recessed trough was then placed in the outer skin of the airplane, to give the bullets a clear path. The doors covering these troughs were intended to reduce the drag produced by these indentations in the otherwise smooth skin of the forward fuselage. When the trigger was pressed to fire the guns, the rear of the door would pull inward, forming an opening for the bullet to exit. The doors were designed to open in 1/20th of a second, so that they would not interfere with the operation of the guns.

The gun doors did work as projected, but two unanticipated problems with them arose. The first was that when they worked properly, they did indeed reduce drag on the airframe by a small but measurable amount, and allowed a small increase in speed. However, the machine guns were air-cooled, relying on airflow to help dissipate the heat that built up when the guns were fired. When the doors closed, they blocked off that airflow, often causing the guns to overheat. The main effect of this overheating was to produce "cook offs". After firing the guns, a round of ammunition was left in the chamber, to be available when the pilot next needed to fire. When the guns got hot enough, this ready round of ammunition could be detonated simply by the heat of the gun itself, firing itself without any input from the pilot. Since the pilot was not squeezing the trigger, the gun doors remained closed, so these "cooked off" rounds simply blasted through the doors, rendering them rather pointless.

A second and related problem with the gun doors was experienced when the F-86 was deployed to Korea. In Korea, the F-86 routinely operated at higher altitudes (40,000+ feet) than

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was normal for units in the United States. At those altitudes, it was found that the gun doors simply froze shut, and would no longer open when the pilot pulled the trigger. The results were the same - a gun door blasted apart by a bullet from its own gun, with the occasional ricochet thrown in for good measure. A basic solution to both problems was to wire the gun doors open. A solution that involved a bit more work for the mechanics, but was more effective, was to remove the doors entirely. Eventually, North American reached the same conclusion, and stopped installing the gun doors during the production run of the F-86A-5.[23]

As mentioned earlier the planes from the initial order of 33 P-86s were designated as P-86A-1s, while the Air Force had then contracted for 190 P-86B aircraft. The B version was intended for operation from rough or poorly prepared airfields. Both the XP-86 and the P-86A-1 aircraft had very narrow tires, especially the main wheels, which would limit them to operating from prepared (concrete or blacktop) runways. These narrow tires were used primarily to fit the tires and all the other systems into the limited space of the wings and center fuselage. The P-86B was to have broader tires, with a widened fuselage to accommodate them, to facilitate its ability to operate from less prepared surfaces, such as dirt strips. However, while still in development, advances in both tire and brake technology allowed North American to obtain the same performance they had intended from the P-86B with the earlier narrow tires of the P-86A.[24] Therefore, on 1 December 1947 North American petitioned the Air Force to change the contract for 190 P-86Bs to 188 P-86As and 2 P-86Cs. On 16 December 1947 the Air Force officially approves the change. The former P-86Bs were redesignated as P-86A-5s. The Air Force would eventually, in June 1948, order an additional 333 F-86A-5s.[25]

There were a number of small but significant changes between the P-86A-1 and the P-

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86A-5. The original P-86A-1s had a curved windscreen of normal plexiglas. This was replaced on the P-86A-5 with a windscreen made from two angled pieces of armored glass. Explosive charges were added to enable the canopy to be blown off in the event the pilot needed to abandon the aircraft. Although a powered ejection seat had been standard beginning with the prototype, the first 33 A-1 models required the pilot to manually jettison the canopy before ejecting. Heaters for the gun and ammunition bays were added also, and some changes were made to the internal lubrication system as well.

During the production run of the F-86A-5, several other changes were introduced. The canopy sealing and defrosting systems were made more effective. The nose gear steering and activation mechanisms were improved. The wing slat mechanism was re-engineered and the electrical system and the brakes were also improved. Perhaps the most significant change however, was the substitution of the J47-GE-7, with 5,340 pounds of thrust, for the trouble-prone J47-GE-1 of the A-1. A few of the last of the A-5s had the J47-GE-13, which gave 5,430 pounds of thrust.[26]

Beginning with the second production batch of 333 F-86A-5s, a new style of drop tank was introduced. The original 206.5 gallon drop tank was considered a "ferry" tank, that is, to be used on non-combat missions to increase the F-86's range. The new drop tanks were smaller, only 120 gallons, and were designed for use in a combat environment, hence called combat tanks.

Although the larger tanks did increase the range of the F-86, their shape (a standard rounded cylinder with tail fins) caused buffeting at the high speeds the F-86 would need in combat situations. Tests showed that the airflow between the tank and the wing at high speeds (Mach .8 and above) became very turbulent, and caused the buffeting. Tests were done with tanks with flat

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tops, which did improve the aerodynamics, but the buffeting was still a problem. Finally, after studying the way various other ordnance was hung below the plane, several flat topped tanks were hung only six inches below the wings, rather than the normal twelve. This solved the buffeting problem, but when the flaps were lowered with the tanks attached, the tanks interfered with the flaps. The solution was to angle the rear of the tanks downward, and add small fins. These new combat tanks could be carried with no adverse aerodynamic effect up to the aircraft's maximum speed.[27]

Two of the initial order of 190 P-86Bs were re-designated as P-86Cs. The P-86C was intended to be a prototype for a long range Penetration fighter, to compete for a production contract from the Air Force. Extensively redesigned, it was eventually re-designated the XF-93, and competed against McDonnell's XF-88 and Lockheed's XF-90 for the Penetration fighter contract. The XF-93 was substantially heavier than the original F-86, as the fuselage had been enlarged to carry additional fuel cells, but had essentially the same power available. This made the XF-93 seriously underpowered, placing it at a considerable disadvantage in the Penetration fighter competition. The XF-93 will be covered in more detail in the chapter on jet fighter prototypes.[28]

Another re-design of the F-86 became known as the F-86D. The F-86D was intended to perform as an interim all-weather interceptor. Unlike the other designs for similar aircraft (XF-87, F-89, F-94) which were two seat aircraft, with a pilot and a radar operator, the F-86D remained a single seat aircraft. A sophisticated radar system was placed in a bulbous nose above a modified air intake, and a special autopilot was added to enable the pilot to fly the plane and operate the radar system simultaneously. Both systems were very complex, and would give considerable trouble throughout the F-86D's career. To enable the F-86D to catch the high speed

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jet bombers, it was to be given an afterburner for its J47-GE-17 engine. One of the most unusual modifications to the basic F-86 for the D version was the deletion of the machine gun armament. The F-86D was instead armed with a retractable tray on the underside of the forward fuselage. Twenty four 2.75 inch "Mighty Mouse" FFARs (Folding Fin Aerial Rockets) were carried in the tray, to be launched at opposing bombers.[29]

The program to modify the F-86A-5 to the D configuration was begun in June 1949. Several aircraft, including the F-86, that were undergoing significant modification at that time were initially given different numerical designations in late 1949, and then switched back to the original numbers in 1950. This was the result of defense department politics. The Air Force originally hoped to get additional funds from Congress for "new" airplanes by changing the designation of these modified versions. Then with the outbreak of the Korean War, the Air Force felt that it would be easier to get funding for existing aircraft rather than "new" ones, so the numbers were changed back. The modification of the F-94B interceptor to carry rocket pods rather than cannon was initially known as the F-97, and then it became the F-94C. The swept-wing version of the straight wing F-84 became the F-96, then reverted to the F-84F. And the interceptor variant of the F-86 became first the F-95 and then the F-86D. Additional discussion of the F-86D will be given in the chapter on all-weather interceptors.[30]

The next version of the F-86 would be the F-86E. The first E versions of the F-86 were contracted for on 11 November 1949. Initially, there were few differences between the first F-86Es and the last of the F-86A-5s. One of the few changes, however, would have an enormous impact on the ability of the F-86 to maneuver at high speeds, which would soon turn out to be vital in combat over a then-obscure Asian peninsula.

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In high speed tests, especially dives, of the F-86A models, two related problems had been encountered. The first was that the ability of the controls to alter the aircraft's position degraded, and the second was a phenomenon known as "control reversal." Both problems were related to the compressibility phenomenon that occurred as an aircraft neared transonic speeds. The turbulent shock waves produced by the speed of the aircraft buffeted the control surfaces. Although hydraulic boost to the controls had partially overcome this problem, the forces remained. The shock waves diminished the effectiveness of the control surfaces, and when strong enough, could actually prevent them from functioning at all. This could cause control reversal, where a pilot in a dive applied controls to climb, only to find that the aircraft refused to respond, and kept diving.

There were two possible solutions to this problem - to increase the area of the control surfaces, especially the elevators, and to increase the hydraulic boost to them. North American chose to do both. However, they did not want to alter the size or shape of the tail surface, so they devised a unique, and revolutionary, alternative. The standard in aircraft design for decades had been to have a fixed horizontal tail surface, the stabilizer, and a moveable part, the elevator. When the pilot pulled back on the stick to climb, the elevators angled up, and when he pushed forward to dive, they angled down. The F-86E, while retaining the traditional separation of elevator and stabilizer, now moved *both* parts when the pilot pushed or pulled on the stick. If he pulled back for a climb, the elevators went up *and the stabilizer went down*. The angle of the elevator movement was steeper than that of the stabilizer, in part because the stabilizer was the larger of the two portions, and did not need to move as much.

The other element of the solution was to strongly increase the hydraulic boost of the tail

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control surfaces. This did allow the easier movement of the control surfaces at high speeds, but it had an unanticipated side effect. During early tests of this new system, it was found that it greatly reduced the pilot's "feel" for how the airplane was handling. Ironically, the movement of the control surfaces had now become too easy, and this affected the pilot's judgement about how the aircraft was flying, and could prove deadly. So North American, while retaining the extra boost, had to build "feel" into it, so that pilots got some resistance when maneuvering the plane. Authors writing about the F-86 have compared the phenomenon to the need for auto makers to build "feel" into hydraulically powered automobile steering systems, for the same reason.[31]

These modifications vastly increased the effectiveness of the tail control surfaces for affecting changes in pitch. The new tail surfaces rapidly became known as the "flying" or "steerable" tail, and greatly improved the maneuverability of the F-86 at all speeds, especially the highest combat speeds. Later models of the F-86, particularly the D and H, took the concept a step further and simply made the entire horizontal tail surface a single, solid, moveable unit, which improved maneuverability even further. This was known as the moveable "slab" tail, and would become the standard for all later high speed jet aircraft.

The initial production order for the F-86E was for 111 machines. Of this number, the first 60 were designated as F-86E-1s, and were as described above. The remaining 51 had minor internal improvements, and were designated F-86E-5s. The next model was the F-86E-10, and the primary difference between it and the earlier versions was the replacement of the angled, two piece windscreen with a single, flat piece of optically ground armored glass. The instrument panel was also rearranged, for a clearer view of the important instruments, and some alterations were made to the switches and gauges in the cockpit. The E-10 was actually an interim model. North

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American had planned to transition to the F-86F after the E-5, but a shortage of the newer J47-GE-27 engine, with 5,910 pounds of thrust, meant that 132 of the F-86E-10s were built instead.[32]

There was another E version of the F-86, one which was not produced in the United States. The Canadian based Canadair Ltd., which had license-built the famous North American trainer, the T-6 Texan, during World War II, obtained permission to build the F-86 under licence in Canada for use by Canadian, other Commonwealth, and NATO nations. Canadair obtained a single F-86A-5, and used it as the prototype for beginning the manufacturing. The primary change they made to the American airplane was to put an Avro Orenda engine, with just over 6,000 pounds of thrust in it. This single prototype was identified in North American records as the F-86J, but Canadair called it the CL-13 Mk. 1.

Canadair then proceeded to build 350 CL-13 Mk. 2s, which were identical to the F-86E-1 in every way save for the engine, including the all flying tail. When these machines began to come off the line, in late 1951, the US Air Force was running low on F-86s. The demands of combat in Korea were not being met by the single assembly line North American operated. Although North American would eventually open a second assembly line for the F-86, the Air Force needed more of the planes immediately. So 60 of the Canadair CL-13 Mk 2s were bought from the Canadian company, and designated as F-86E-6s. The only change made to them was to replace the radio and other electronic gear with American systems. The E-6s were then shipped off to Korea post haste.[33]

Production of the F-86 now shifted to the F version, but the E refused to simply fade away. When, during the assembly of F-86F-15s, continued shortages of the J47-GE-27 engine forced North American to use older -13 engines, the resulting planes were designated as F-86E-

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15s. These E-15s had all of the improvements of the F series up to that point, and were often retrofitted with the newer engines and other features of the later F models.

On 31 July 1950, a contract for 360 F models of the F-86 was issued. The first of the F series were essentially F-86E-10s that were given the larger J47-GE-27 engine. This engine substantially improved the performance of the F-86. Top speed improved to 695 mph, rate of climb went to 9,850 feet per minute, and the service ceiling increased to 49,100 feet.[34]

There were a great many sub-types of the F model of the F-86. The F-86F-1 is described above. The F-86F-5 added a reinforced wing, to accommodate additional hard points for carrying external ordinance. The F-86F-10 added the new and simpler A-4 radar gunsight with APG-30 ranging radar. Minor internal modifications resulted in the F-86F-15 and F-86F-20. In addition, North American had opened a second manufacturing facility in Columbus, Ohio. This new plant produced the F-86F-20 and F-86F-25. The original California plant produced the other models. The F-15, when produced at the Columbus plant and with the addition of a new radio system, was the F-20, and the F-30 produced at Columbus was the F-25.[35]

Beginning with the F-25/30 series, two significant improvements were made. The first was the addition of an extra set of hard points on the now-strengthened wing, allowing the F-86 to function as an effective ground attack machine for the first time. Although all F-86s had the capacity to carry external stores, without external fuel tanks they had a very limited range. When carrying the fuel tanks, there was no room for much external ordinance, although a few rockets could be carried outside of the tanks. The F-86F-30 was the first effective fighter-bomber version of the F-86.

The other big change with the F-25/30 series aircraft was the removal of the leading edge

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slats. Enough experience had now been gathered on the handling of the F-86 to predict that experienced pilots could handle the loss of lift and stability at low speeds, and removing the slats would improve the airflow at high speeds. This led to the creation of the so-called "6-3 hard wing".

With the new wing, the leading edge with its slats was removed, and replaced with a solid leading edge. This new wing edge was six inches wider at the root and three inches wider at the tip, and therefore referred to as the 6-3. These added inches altered the angle of the wing sweep, and gave the F-30 a great deal of extra maneuverability at high altitudes and speeds. In Korea, Sabres were engaging in high speed combat with MiG-15s at very high altitudes, so the extra performance resulting from these modifications was a crucial advantage. The new leading edge, since it was solid, was also used to give the F-86 an additional 130 gallons of internal fuel capacity. A six inch upright piece of metal, usually referred to as a "fence," was added at 70% of the distance out from the wing root, to smooth out the airflow over the wing. The new leading edge did extend over the machine gun ammunition bay doors, which meant that a small portion of this leading edge was removable so the doors could be opened. And because this new leading edge was such a simple modification, it was also manufactured in kit form, and the kits shipped to Japan, where many of the earlier F models, as well as some of the late E models, had it fitted.[36]

Two further F models of the F-86 were built. The F-35 had additional external bracing and the LABS (Low Altitude Bombing System) to enable it to deliver nuclear weapons. The intended tactic for such delivery had the F-86 "tossing" the bomb by climbing. After the bomb was released, the plane would continue the climb into a half-loop, roll upright and streak back the way it had come.

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The F-40 model was intended for export to Japan's newly-established Air Self Defense Force. The pilots of this force had little or no jet experience, so although the F-40 retained the basic 6-3 wing shape, the wing was lengthened by a foot and slats were once again added to the leading edges. These changes made the F-40 very stable at low speeds, and it retained most of its speed and maneuverability at high altitudes and speeds.[37]

The designation F-86G was allotted to a modified version of the F-86D. 406 of them were ordered, but the designation was changed to F-86D-20 before any of them were delivered.

The final, and definitive version of the F-86 was the F-86H. Initiated on 16 March 1951, the F-86H first flew in May 1953. The H was intended to be optimized for ground attack missions without giving up any of the earlier version's performance. Although the F-30 could operate fairly effectively as a fighter-bomber, while carrying heavy loads of ordinance it paid a penalty in range and speed. The H was designed to overcome those limits.

The main ingredient in this redesign was the use of a much more powerful engine, the J73, which could produce 8,900 pounds of thrust. This new engine was much larger than the earlier engines, necessitating a redesign of the fuselage, which was deepened and lengthened. Initially armed with the same six .50 caliber machine guns as the earlier models, it was eventually given four automatic 20 mm cannon. These new cannon actually had a higher rate of fire than the machine guns, (1,500 rounds per minute for the cannon, 1,200 per minute for the machine guns) and could carry almost as much ammunition per gun (150 rounds per cannon to 267 per machine gun).

Although the new and larger version of the F-86 was considerably heavier than the earlier ones (11,038 pounds vs. 14,218 pounds empty, 16,438 pounds vs. 23,782 pounds loaded), the

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new engine gave it superior performance. Top speed increased to 707 mph, service ceiling to 51,100 feet, and rate of climb to 12,160 feet per minute. Combat range was also increased by over 100 miles on internal fuel alone. The Air Force ordered a large number of the H variant, and there were several sub-variants. It was, however, the only day fighter version of the F-86 that did not see combat, as the first examples did not reach Air Force units until the fall of 1954. Despite being the ultimate expression of the swept-wing F-86 design, it quickly became a second-line combat aircraft because of still newer aircraft, such as North American's own F-100 Super Sabre. Thus the F-86H was quickly relegated to Air National Guard units, where it continued to serve with distinction into the 1960s.[38]

The F-86 equipped a small number of Air Force units prior to the Korean War. The first unit to receive the F-86 was the 94th Fighter Squadron of the 1st Fighter Group. The 1st FG was the same unit that had, under the designation 412th Fighter Group, been equipped with first with the P-59 and then the P-80. Redesignated as the 1st Fighter Group, and eventually the 1st Fighter Interceptor Wing, it now became the first to receive the F-86. The first examples of the F-86A-5 equipped the 94th Fighter Squadron, along with some earlier F-86A-1s for transition training. The 94th FS received its first examples of the new fighter on 15 February 1949. The 1st FG received its entire compliment of F-86A-5s by May 1949.[39]

It was the 1st FG that was responsible for giving the F-86 its distinctive name. North American had referred to the F-86 unofficially as the "Silver Charger." As the 1st FG was transitioning into their new mount, they held a contest to come up with a distinctive name for the sleek and angular aircraft. Many entries were submitted, but the one that prevailed was the simple and descriptive "Sabre." The Air Force quickly and enthusiastically adopted the name, and the F-

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86 became the Sabre. The news media and publicists often lengthened the name to SabreJet, which fit in nicely with Republic's F-84 Thunderjet and Grumman's F9F Panther Jet. But the official name of the F-86 has always been the more simple and elegant "Sabre."[40] The more trouble-prone F-86D version was frequently know to its pilots and crew as the Dog Sabre or Sabre Dog, not in an affectionate sense at all.[41]

These first examples of the F-86 did not quite have all the bugs worked out of them yet. Pilots of the 94th FS, in particular, had a number of unpleasant experiences with the early machines. The slat mechanism was still trouble prone, and there were problems with the flight controls as well. It was not unknown for the early F-86s to begin uncontrollable "porpoising" or similar maneuvers, if the pilot overcompensated on the controls. Some of the cockpit components broke or malfunctioned as well. Despite the feelings of the pilots of the 94th FS, most of the problems were worked out quite quickly, and the F-86 would prove to be well-like by most of its pilots.[42]

The 1st FG was an ADC unit, as were all the other units to receive the F-86 prior to the outbreak of the Korean War. In an interesting coincidence, the 1st FG was tasked with defending the southern California area, which included the city of Los Angeles and the North American factory itself. The other units that received the F-86A-5 before the Korean War were the 4th Fighter Group, defending the Washington, D.C. area, the 81st Fighter Group, defending the southwestern desert, especially the nuclear research and test facilities, the 33rd Fighter Interceptor Group at Otis Air Force Base in Massachusetts, the 56th Fighter Group at Selfridge Air Force Base in Michigan, and the 23rd Fighter Interceptor Group at Presque Isle Air Force Base in Maine. No F-86s were deployed overseas prior to the Korean War. When earlier A models of

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the F-86 were modified to the standards of later aircraft, these rebuilt aircraft, designated as the F-86A-6 and F-86A-7, were assigned to various Air National Guard units in the United States.[43]

When the Korean War broke out, it was originally anticipated that the Far East Air Force (FEAF) could handle the situation with the aircraft on hand. These included F-51 Mustangs and F-80 Shooting Stars. Against the small, World War II vintage North Korean Air Force, this was an accurate assumption. Once the FEAF entered the action, the North Korean Air Force was quickly eliminated as a combat presence, although their night harassment aircraft, Russian-built Po-2 fabric-covered biplanes, known to Americans a "Bed Check Charlies," continued to operate throughout the war.

When the new swept-wing Russian MiG-15 was encountered in the skies over northern Korea, it was obviously superior to any of the American aircraft deployed in the Far East at that time. Thus the decision was made to send the latest and best fighter in the Air Force's inventory, the F-86, to Korea. The 4th FG was quickly dispatched to Korea with its F-86A-5s, where they were expected to quickly restore American air superiority. Combat in Korea proved to be intense, and high losses, from combat, accidents, and wastage, meant that numerous replacement aircraft were needed. These were initially obtained by taking them from other fighter groups in the United States equipped with the F-86, as there were no surplus aircraft to replace combat losses.

As air superiority in Korea proved more difficult to establish than the Air Force had anticipated, a second unit of F-86s was felt necessary. This was the 51st FIG, already operating F-80Cs in Korea. When the F-86E model became available, the first examples, enough for just one squadron, were sent to the 33rd FIG at Otis AFB. As soon as the 33rd FIG was able to

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bring these aircraft to operational status, the remaining F-86Es were shipped to Korea, where they were divided between the 4th FIG and 51st FIG. The 51st FIG was eventually totally re-equipped with F-86s, first two squadrons (16th and 25th) in December 1951, and by June 1952, the remaining 39th. These two air superiority groups would eventually be joined by the 18th Fighter Bomber Wing, converting to F-86F-30s from the F-51D Mustangs they had been operating since the beginning of the war, and the 8th Fighter Bomber Wing, converting to F-86F-30s from F-80Cs. Both of these units received their Sabres in early 1953.[44]

As long as the war lasted, the units in Korea (the 4th and 51st) had first priority on new models of the F-86. Once North American got their new plant in Columbus, Ohio, operational, they finally had the capacity to meet the demand in Korea and begin to re-equip units in the United States. Almost the entire production run of Columbus-built F-86F-25s, which were virtually identical to the F-30 model, went to Air National Guard units. When the war ended, other units, both in the United States and Europe, received the Sabre. The F-35 variant, able to deliver nuclear weapons, went almost entirely to European-based units. The final H version went largely to Air National Guard units, as more advanced designs were becoming available by the time it reached full production.

There were two programs involving modification of F-86s, both tied to the needs of the Korean War. The first was brought about by the need for high-speed tactical reconnaissance aircraft. Initially, camera equipped RF-51s and RF-80s were more than adequate for the job, but once the MiG-15 entered the conflict, any attempt by these planes to obtain pictures within the range of the MiG was dangerous in the extreme. What was needed was a photo plane with the speed to evade the MiG. Only one such plane existed - the F-86. But there was no dedicated

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reconnaissance version of the F-86, nor any plans to build one.

Several officers of the 15th Tactical Reconnaissance Squadron, based at Kimpo airfield, decided to take matters into their own hands. Obtaining the forward portion of a scrapped F-86A fuselage, they began to experiment with a means to install the necessary cameras in it. By removing the gun and ammunition bays, and using a bomb recording camera "borrowed" from a B-26 bomber, they managed to create a reconnaissance mount. Because of space limitations, the camera could not be mounted pointing directly downwards, so it took pictures by using a 45 degree angled mirror reflecting from a hole cut in the bottom of the fuselage. It was a cobbled-together lashup, but it worked, and permission was obtained to modify a pair of flyable aircraft in the same manner.

The 4th FIG contributed a pair of combat weary F-86A-5s. These planes had the camera installed on the left side, leaving the entire right side gun bay, and the two top guns in the left bay. Externally these planes were identical to normal fighter version F-86s. The only physical difference was a small hole in the bottom of the forward fuselage. In keeping with (and poking fun of) the Air Force policy of giving names to special aircraft modification project, these two aircraft were known as HONEYBUCKETS.[45] Although they did the job, they were not ideal, and the two of them alone could not adequately handle the necessary photographic missions. Moreover, the photographs taken by these planes were not of very good quality, as there were problems with the mirrors vibrating, which blurred the pictures.

So the decision was made to create still more RF-86A conversions for photo reconaissance. This was labeled project ASHTRAY. These conversions were essentially hand built in Japan, and therefore had minor variations. All ASHTRAY Sabres used two cameras, thus

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necessitating the removal of both gun bays. Some of the aircraft retained the upper gun in each bay, while others removed all of them. The mirror mounts were strengthened against vibrations. Sources differ on the number of F-86As converted in this manner, but the number was between eight and fourteen. No more than six of those planes operated in Korea at any given time.

The success of the ASHTRAY conversions in turn led to a more standardized photo conversion, of F model Sabres this time. These conversions were labeled project HAYMAKER, and the conversion work was done by the Tsuiki Remco company in Japan. They used larger cameras necessitating the addition of small bulged compartments just in front of the forward wing root. These conversions reached the combat theater in the spring of 1953. North American also produced a handful of factory built photo versions - true RF-86s. Also based on the F model, these used still larger cameras, requiring a distinctive bulging of the fuselage below the cockpit. At least two of these aircraft reached Korea before the end of the fighting, and South Korea employed a small squadron of them for some time after the war.[46]

The other project involving modified F-86s was project GUNVAL. A problem noted by Sabre pilots almost as soon as they began encountering MiG-15s was the difficulty of shooting down the Russian built plane. The problem was not the difficulty in hitting the MiG, but rather the inability of the Sabre's six .50 calibre guns to inflict the necessary fatal damage. It was not uncommon for a Sabre pilot to empty his entire ammunition load during combat with a MiG, only to have it flee with smoke billowing, back across the Yalu River. The difficulty the Sabre pilots had downing MiGs can be seen in that the top-scoring American ace in Korea, Captain Joseph McConnell, only had 16 kills, despite flying repeated missions in what pilots would call a "target rich environment." There were only ten American pilots who managed to score ten or more kills,

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despite the Amercian pilots having much higher standards of training, better tactics, and a generally plentiful supply of targets. And only handful of pilots managed to down two MiGs in a single mission, and no one ever got three.

For these reasons an attempt was made to increase the hitting power of the Sabre. Four F-86Es and six F-86Fs were modified by North American on the assembly line to carry the Ford-built T-160 automatic 20 mm cannon. Boasting an extremely high rate of fire (1,500 rounds per minute) and high muzzle velocity, the T-160 promised to be an extremely hard hitting weapon. Because of the size of the weapon compared to the machine guns, only two per side could be carried, and the gun bays had to be lengthened. The cannon-armed Sabres were designated as the F-86F-2. After successful initial testing in California, these ten aircraft were sent to Korea for field testing in a combat environment.

One thing that was quickly discovered was that when operating at combat altitudes (40,000+ feet), only two of the cannon could be fired at one time. Much of the exhaust gas produced by firing the guns would be sucked into the engine intake, and if all four guns were fired simultaneously, the quantity of exhaust gas was sufficient to stall the compressor, causing an engine flame out. Two of the test aircraft were lost to engine flame outs during missions.

But even restricted to firing just two guns, the GUNVAL Sabres proved the worth of the cannon. GUNVAL Sabres encountered MiGs on 41 missions. Their score was six MiGs destroyed, three probably destroyed, and thirteen damaged. Given that there were never more than six of the GUNVAL aircraft in Korea at any one time, and that no more than one would fly in a flight of four, and compared with the scores for regular Sabres in similar conditions, these were very impressive scores.

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The GUNVAL airplanes would remain the only cannon-armed Sabres in Korea. By the time the problems, especially the exhaust gas venting, were solved, the conflict had wound down. The T-160 cannon armament would go on to become the standard gun armament on the next generation of American jet fighters, including the last of the Sabres, the H model.[47]

The swept-wing F-86 Sabre proved to be not only the best of the first generation of the American jet fighters and the salvation of the air war in Korea, it also pointed the way to the future of the jet fighter. Swept wings, supersonic speed and increasingly powerful armament were now understood as the wave of the future.

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1. Maurice Allward ***F-86 Sabre*** New York: Charles Scribner's Sons, 1978, p. 63.

2. Morgan ***Me 262: Stormbird Rising***, p.130.

3. Various sources cite the sweep back of the design as between 30 and 45 degrees. 35 degrees is the most common figure, and as that would be the eventual sweep back angle of both the F-86 and the MiG 15, seems to be the most accurate figure.

4. Allward ***F-86 Sabre***, p.17.

5. Hughes & Dranem ***F-86 SabreJet***, p. 14.

6. Allward ***F-86 Sabre***, pp. 19-20.

7. Davis ***F-86 in Action***, p. 5.

8. Hughes & Dranem ***F-86 SabreJet***, p. 13.

9. Robert F. Dorr, Jon Lake & Warren Thompson ***Korean War Aces: Osprey Aircraft of the Aces Number 4*** London: Osprey Aerospace Publishing, 1995, p. 33.

10. Dorr ***F-86 Sabre***, p. 9.

11. Hughes & Dranem ***F-86 SabreJet***, p. 100.

12. Ibid., p. 18.

13. Ibid., pp. 18-20.

14. Ibid., p. 20.

15. Ibid., pp. 20-2.

16. It is also considered possible that two wartime German aircraft, the Me 262 and Me 163, might have exceeded Mach 1 in a dive. The Me 163, in particular, had excellent high-speed handling, and even without power, could reach speeds in excess of 400 mph in a dive. There was, however, no way to verify if either aircraft actually had exceeded Mach 1, so Yeager's record is still the official one.

17. Ibid., pp. 25-6.

18. Ibid., p. 100.

19. Ibid., p. 18.

20. Ibid., pp. 26, 30-35.

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21. Ibid., pp. 26-7.

22. Ibid., pp. 32-5.

23. Dorr ***F-86 Sabre***, p. 13.

24. Davis ***F-86 in Action***, p. 9.

25. Hughes & Dranem ***F-86 SabreJet***, p. 100.

26. Ibid., p. 28.

27. Ibid., pp. 28-30.

28. Davis ***F-86 in Action***, pp. 15-6.

29. Dorr ***F-86 Sabre***, pp. 16-8.

30. McLaren ***Republic F-84***, p. 18.

31. Hughes & Dranem ***F-86 SabreJet***, pp. 42-8.

32. Ibid., pp. 48-51.

33. Ibid., pp. 51-4.

34. Ibid., pp. 58-60.

35. Ibid., pp. 64-70.

36. Ibid., pp. 70-4.

37. Ibid., pp. 75-8.

38. Davis, ***F-86 in Action***, pp. 50-4.

39. Hughes & Dranem ***F-86 SabreJet***, p. 100.

40. Ibid., p. 36.

41. Dorr, ***F-86 Sabre***, p. 17.

42. Ibid., pp. 12-3.

43. Hughes & Dranem, ***F-86 SabreJet***, p. 36.

44. Ibid., pp. 49-50, 74-5.

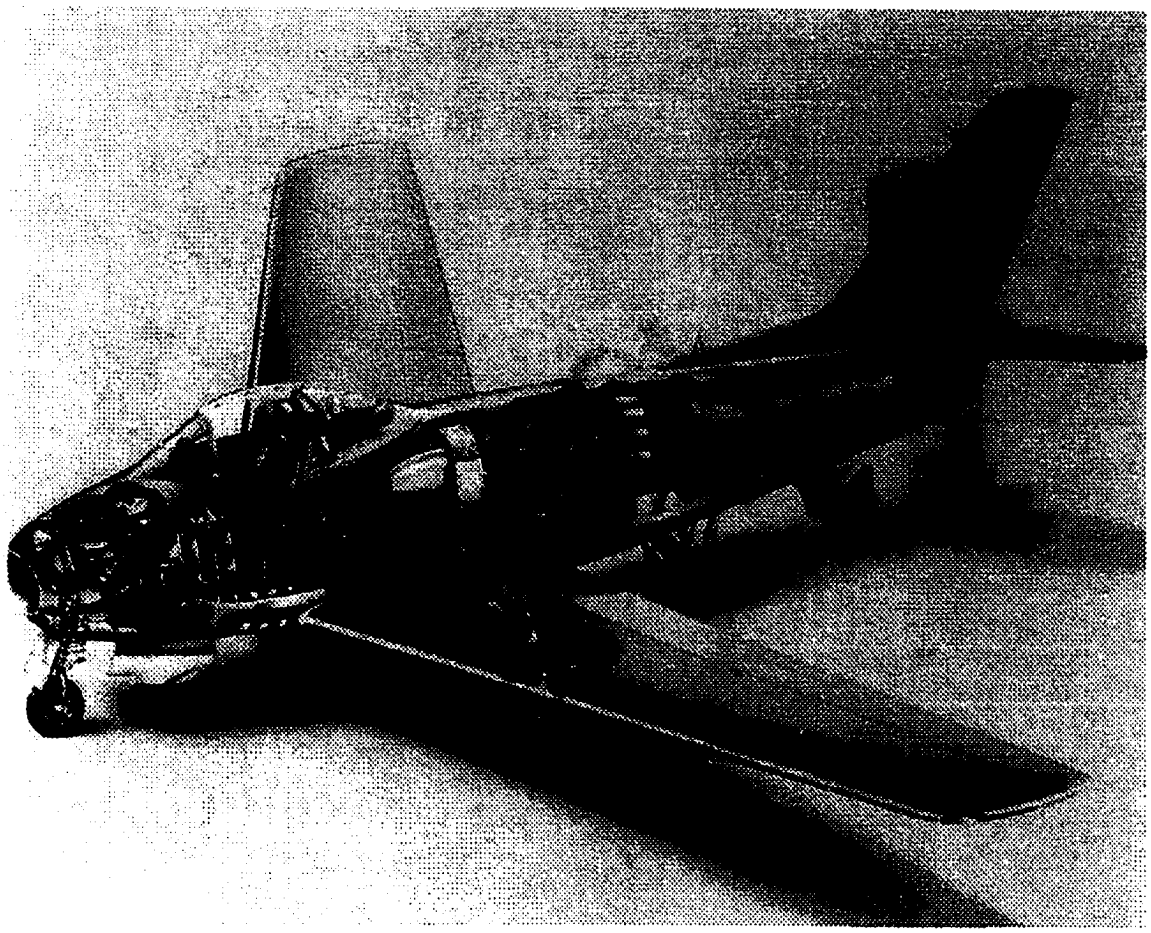
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45. In the early days of aviation, the honeybucket was an pail kept in the plane as a place for people to relieve themselves - aviation's equivalent of the chamber pot.

46. Ibid., pp. 37-41, 84.

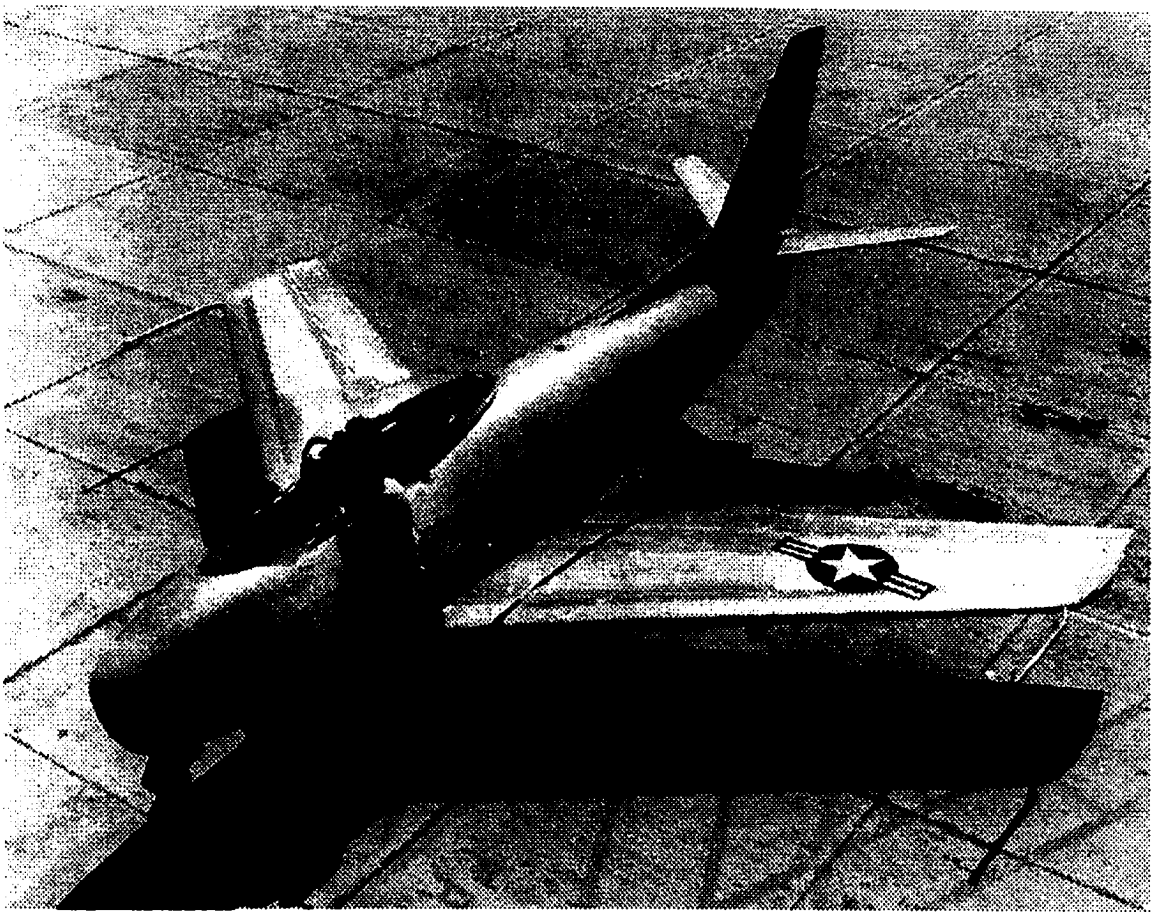
47. Ibid., pp. 79-84.

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Cutaway drawing of the original XP-86 swept-wing prototype. Note the large fuel cells in the inner wings. There are a number of differences between this drawing and subsequent production machines. The panel attached to the nose wheel was hinged and folded outward on production machines. The three speed brakes of the original prototype can be clearly seen, the two on the side of the fuselage and the one on the bottom. Note that the side speed brakes open to the rear. Photo credited to North American Aviation, dated 30 September 1947. (National Archives, Photographic Division, Box 2032, Number 30499)

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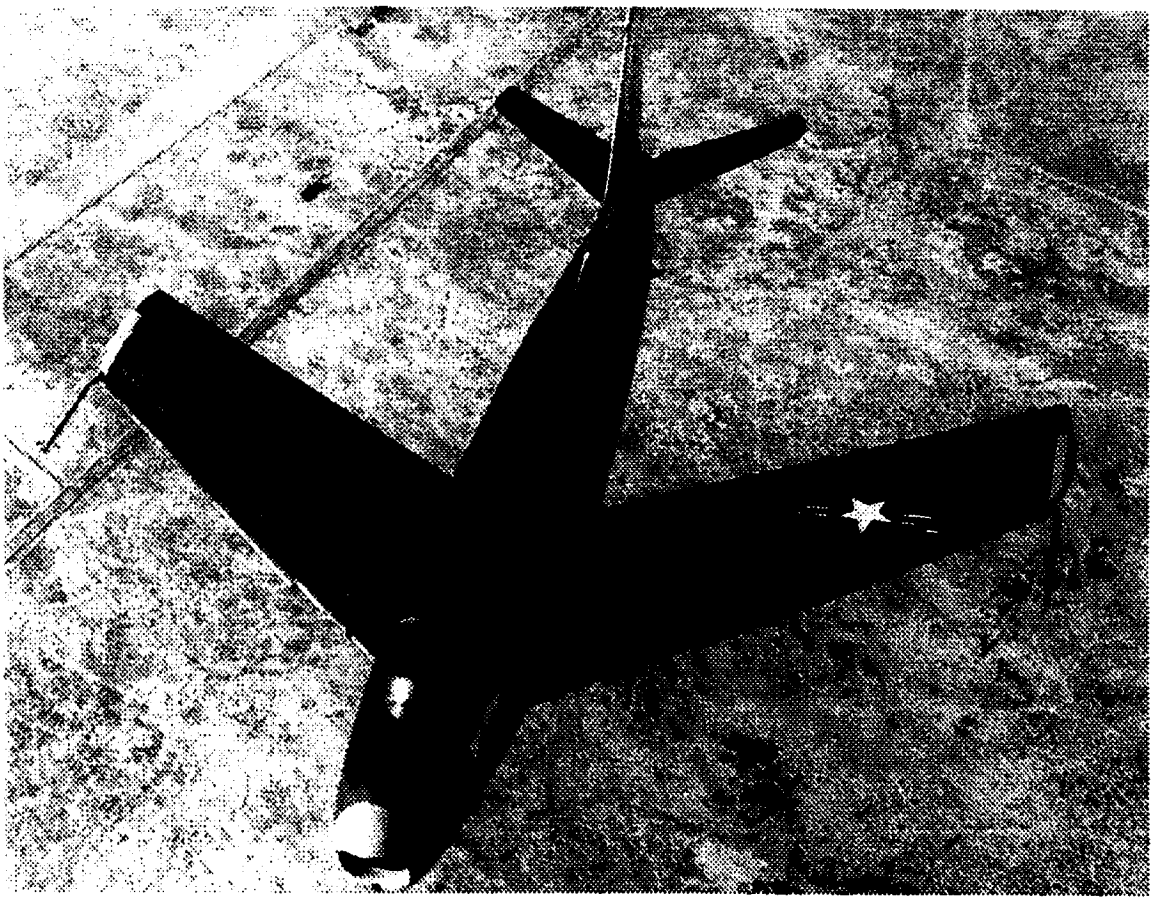
The original XP-86 prototype with North American George "Wheaties" Welch at the controls, receiving last minute information from a ground crewman. This aircraft had large pitot tubes for instrument readings on both wingtips and the top of the vertical stabilizer, which production machines did not have. Production machines had a single small tube on the right wing. Note that this plane carries no armament, and is still designated as P for Pursuit, as seen in the buzz number to the rear of the national insignia on the fuselage. Photo credited to North American Aviation, dated 19 November 1947. (National Archives, Photographic Division, Box 2032, Number 30502)

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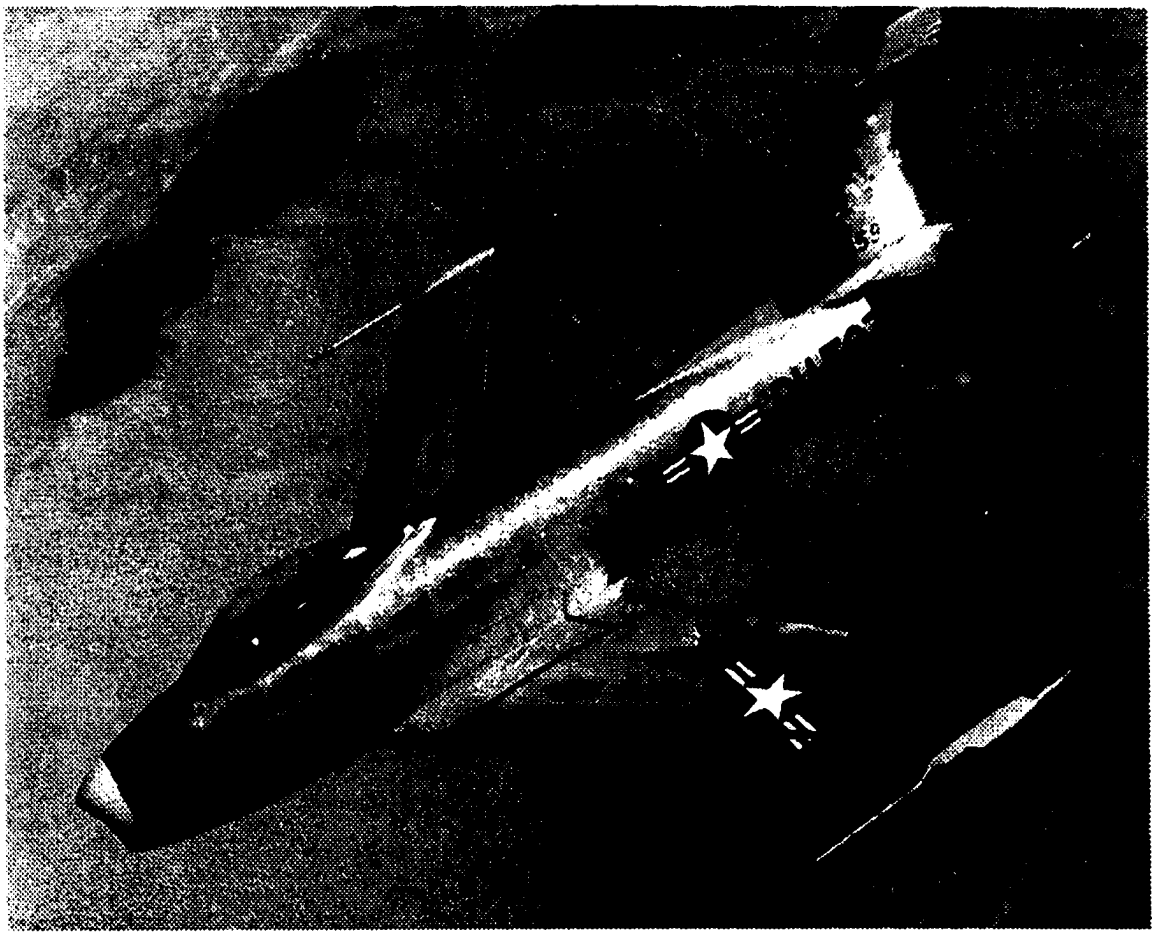
The XP-86 from the rear. The sense of speed imparted by the plane is obvious even when parked on a runway. The original caption reads "The wings of the XP-86 are a thin laminate sandwich". Photo credited to North American Aviation, dated 19 November 1947. (National Archives, Photographic Division, Box 2032, Number 30503)

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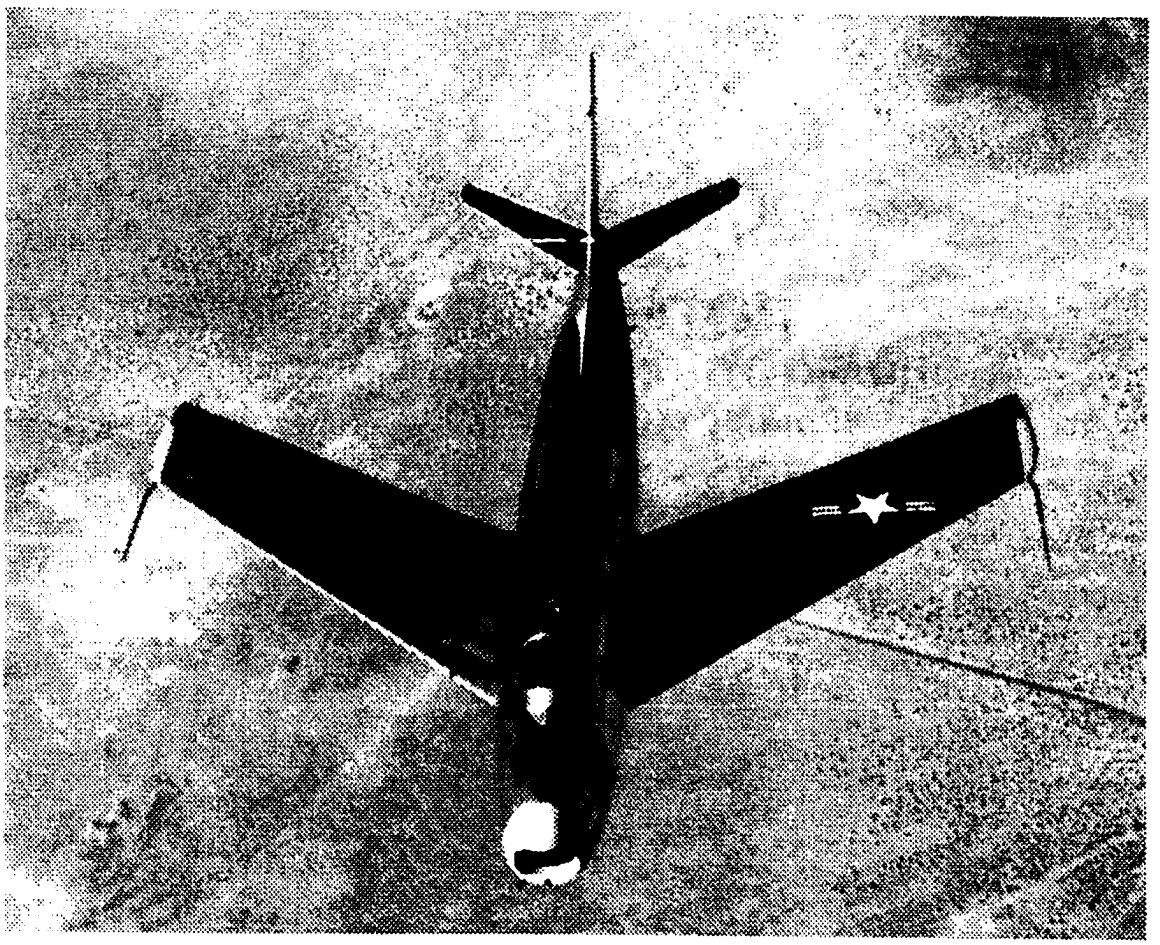
The XP-86 in flight over Muroc, with George "Wheaties" Welch at the controls. Note the leading edge slats on both wings are deployed to assist the plane in slow stable flight for the photo plane. Photo credited to North American Aviation, dated 19 November 1947. (National Archives, Photographic Division, Box 2030, Number 30504)

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The XP-86 in flight, from the side. The Sabre is not diving, it only appears to be doing so because of the angle of the photograph. Again the deployed slats are obvious. Photo credited to North American Aviation, dated 19 November 1947. (National Archives, Photographic Division, Box 2032, Number 30505)

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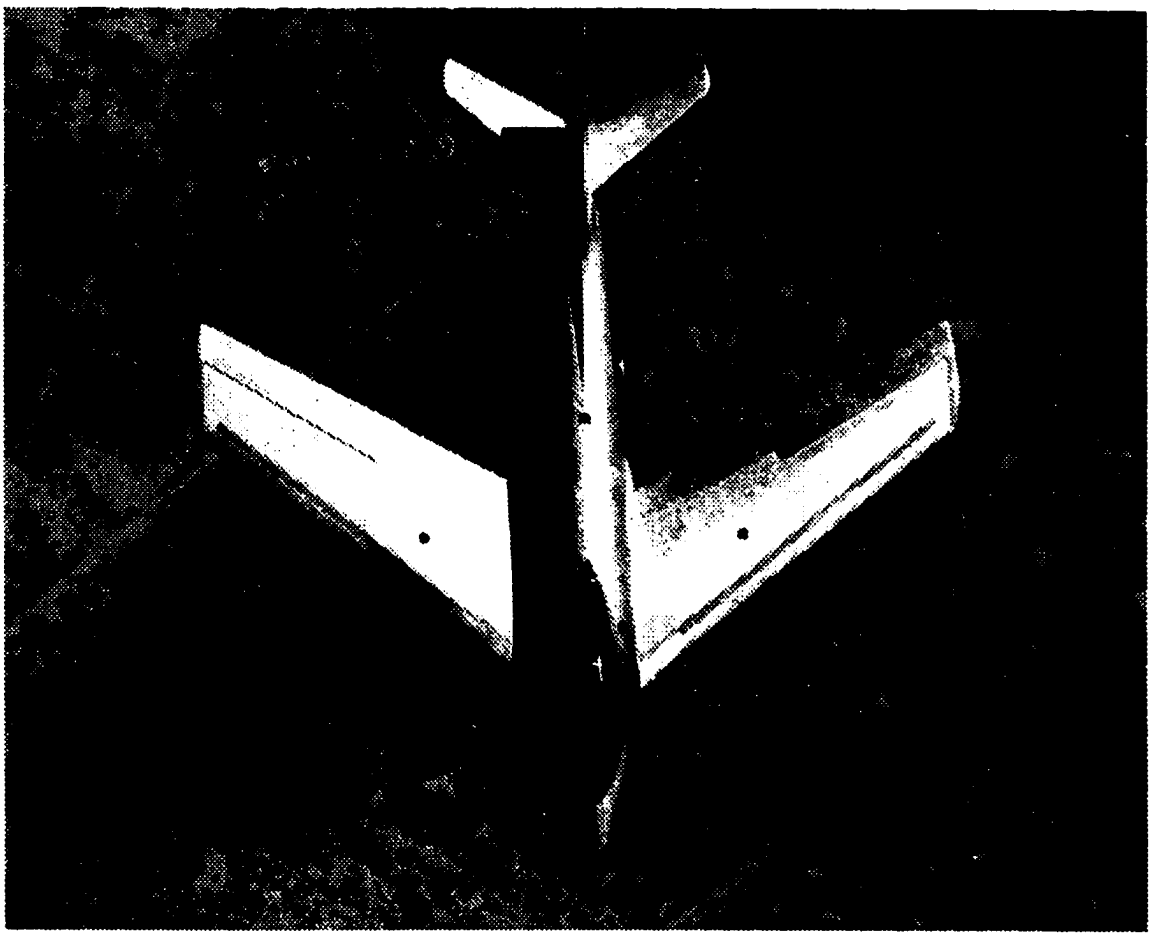
The XP-86 on a test flight. Photo credited to Air Force Office of Public Relations, dated 7 April 1948. (National Archives, Photographic Division, Box 2220, Number 4A-21272)

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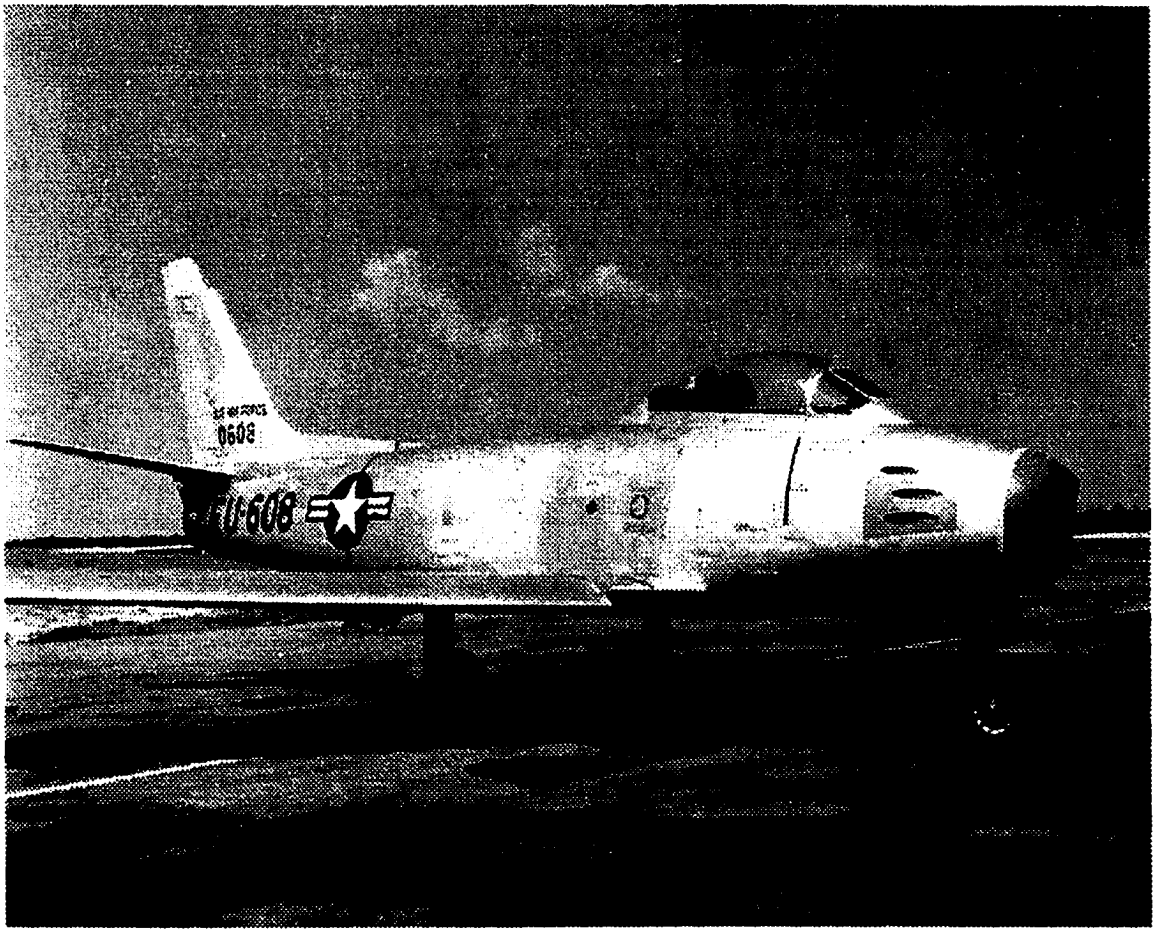
F-86A-5s of the 1st Fighter Group flying over southern California. The distinctive "flame" insignia of the 1st FG can be seen on the fuselage of all four aircraft. The flame portion of this insignia varied depending on the squadron, blue for the 94th FS, and red for the 71st FS. The small doors covering the gun ports can be seen on the nose of these aircraft. Photo credited to 1st Fighter Group, March Air Force Base, California, dated 14 April 1950. (National Archives, Photographic Division, Box 2032, Number 30541)

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An F-86A from above. The clean lines and sleek design of the airplane are evident from this angle. Photo credited to North American Aviation, dated 22 June 1951. (National Archives, Photographic Division, Box 2032, Number 30585)

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An F-86E-1 undergoing tests at Eglin AFB in Florida. A rack for external fuel tanks is located under the wing to the left of the landing gear, and the new flat armored glass windscreen can also be seen. The darker color of the air intake is because the entire piece was constructed of fiberglass, and was left in the original color of the material. Photo credited to Eglin Air Force Base, dated 17 July 1951. (National Archives, Photographic Division, Box 2032, Number 30515)

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"...the Air Forces had a definite and almost desperate requirement for a defensive fighter with which to counter any air attack against the United States or any U.S. installation, and that the fighter had to ... be capable of operating day or night in any weather."
Major General Grandison Gardiner, Office of the Secretary of the Air Force[1]

Chapter 10
"Neither Snow nor Rain nor Gloom of Night...": The Development of All-Weather Interceptors

In the early years of powered flight, the vast majority of flying was done during daylight hours, on sunny, clear days. This was due in part to the fragile nature of the early flying machines and their inability to safely sustain damage caused by inclement weather. But the primary reason for this restriction of flying to daytime was the fact that human beings depend overwhelmingly on their sense of sight to find their way through the world. During stormy, cloudy weather, or at night, the sense of sight is extremely limited in effectiveness. Attempting to fly an airplane under these conditions almost invariably led to serious problems, as illustrated by the pilot in one of Gary Larson's 'Far Side' cartoons who asks "Say...What's a mountain goat doing way up here in a cloud bank?"[2]

Nonetheless, during World War I, some flying began to be done during nighttime. Germany, in an attempt to retaliate for the British naval blockade, used a number of the giant Zeppelin airships to bomb cities in England. As the Zeppelins were both immense targets and full of highly flammable hydrogen, they proved to be vulnerable to interception by British fighter planes firing incendiary bullets. For concealment the Zeppelins then switched to night bombing raids. Bombing accuracy deteriorated somewhat during the darkness, but the Zeppelins were hardly precision bombing instruments to begin with, and there were never more than a handful of

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them, so their overall performance remained similar to what it had been during daylight hours. By operating at night they were, initially, immune to fighter interception.

It did not take the newly-formed Royal Air Force long to begin attempting night interceptions of the Zeppelins, however. Volunteer pilots (of whom the future World War II commander of Bomber Command Arthur Harris was one) took off from farmer's fields at night in their fragile fabric-covered biplanes and attempted to locate the Zeppelins visually and destroy them. They succeeded often enough to force the Germans to halt Zeppelin bombing raids altogether. Because most of these interceptions took place on bright moonlit nights, and because the fighter aircraft had very low landing speeds, the British pilots often survived the attempts.

Eventually the Germans shifted their night bombing efforts to their Gotha and Staaken bombers. Smaller than the immense Zeppelins, these airplanes proved to be much harder to intercept, even if they were no more accurate at night than the Zeppelins had been. Late in the war, the Royal Air Force began a similar program of night bombing of German cities, using their Handley/Page bombers. The memory of these efforts would shape the Second World War's night air operations.

In the inter-war period, as aircraft got larger and more complex, operating at night became more practical, especially for multi-engined aircraft such as bombers. In addition to the pilot, a bomber could carry additional crewmen such as a navigator and a radio operator, who could assist the pilot in night navigation. Also, improved instrumentation, radios, and reliable aircraft lighting (both exterior landing and position lights and interior instrument lights) made it possible for aircraft to operate during nighttime.

As part of their preparation for eventual conflict, in the late 1930s the new Luftwaffe

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began to develop several devices and techniques to make night operations more practical and night bombing more accurate. Early German devices included *Knickebein*, a radio navigation system, and *X-Gerat*, a radio blind bombing technique. Both worked quite well, producing good results in initial usage, but both were also very vulnerable to jamming, as the Germans discovered during the Battle of Britain.[3]

England's primary contribution to nighttime aerial warfare would prove to be much more long-lived and useful. This was the device that would be known as RADAR (RAdio Detection And Ranging). By sending out pulses of radio waves and examining the reflection of these pulses off solid objects such as airplanes, aircraft could be detected at distances far greater than the human eye could perceive. England's network of Chain Home radar stations was perhaps the most important factor in her narrow victory over the Luftwaffe during the Battle of Britain. The earliest radar installations were large and bulky, confining them to ground stations

After the Battle of Britain, when the Royal Air Force attempted to strike back at Nazi Germany, they quickly discovered that bombing missions in daylight beyond the range of fighter escorts were suicidal. As British fighter aircraft were very short-ranged, and no serious attempts were being made to produce long-range fighters, the decision was quickly made to begin bombing at night. This set in motion a continuous series of electronic innovations by both the British and the Germans, including various types of advanced radar, radar spoofing (window or chaff) and jamming, more sophisticated radio navigation, and most importantly, the mounting of radar sets in aircraft, in an attempt to both improve accuracy in bombing and to locate other aircraft in the darkness.

The British had first attempted to use airborne radar to detect enemy aircraft during the

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latter stages of the Battle of Britain, known as the Blitz, when the Germans bombed British cities at night. Small, short-ranged radar, or AI (Airborne Intercept) sets were mounted on various medium bombers and fighters, such as the Blenheim, Defiant, and Beaufighter, with modest success. But the Germans, in attempting to counter the increasingly powerful Bomber Command night raids, would be the ones to develop the greatest variety and numbers of this new class of "night fighters."

The term night fighter is somewhat misleading, as these aircraft were (with a few exceptions, such as the Mosquito and P-61) intended primarily to locate and destroy enemy bombers, not to combat other fighters. In fact, most of the night fighters employed by the various air forces during the war were either converted multi-engined fighters or medium bombers. This was due to the bulk and complexity of the early airborne radar sets, which generally required an additional crewman to operate them effectively. Attempts were made to use single-engine, single-seat fighters as night fighters, with mixed results. The Germans installed radar on several of their single-seat fighters, such as the Fw 190 and Me 262, with limited success. The American Navy installed radar on several of its single seat fighters, including the F6F Hellcat and F4U Corsair, with better results, although these planes often worked in close conjunction with carrier task forces and the sophisticated ship-borne radar systems, which lessened the need for the pilots to rely on their own radar.

The Germans would eventually put radar sets in almost all of their multi-engined aircraft. Some of their most effective night fighters were radar-equipped versions of the Me 110 heavy fighter and the Ju 88 medium bomber. The British would also put radar on their Beaufighter heavy fighter and Mosquito fighter-bomber. The Mosquito, in particular, proved to be a potent

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night fighter, and by hunting the hunters made operations very dangerous for German night fighters, as it was faster and more maneuverable than its German counterparts. Towards the end of the war, the Germans did produce small numbers of purpose-designed night fighters, including the He 219 *Uhu* (Owl) and Ta 154 *Moskito* (Mosquito). Both the two-seat training version of the Me 262 and the Ar 234 jet aircraft were also equipped with radar as night fighters, the night-fighter version of the Me 262 proving to be one of the few German aircraft capable of easily shooting down British Mosquitos.

American air force doctrine during the inter-war years had stressed the utilization of daylight "precision" bombing, utilizing the top secret Norden bombsight, supposedly able to "put a bomb in a pickle barrel from 20,000 feet."[4] The heavy clouds of northern Europe defeated much of this accuracy, and the fighters of the Luftwaffe savaged the unescorted bombers. During the devastating losses of 1943 the American 8th Air Force in England actively began planning a switch to night bombing operations, but the arrival of the long-ranged P-51 Mustang ended the need for this, and the daylight operations continued. Thus the American need for night-capable aircraft in Europe proved to be minimal, despite earlier predictions.

Likewise, in the Pacific, most of the air combat activity took place during daylight hours, until the night bombing missions over the Japanese home islands very late in the war. There was a need for night-capable aircraft there, though, to deal with Japanese night bombing harassment raids. The original American night fighter was a conversion of the Douglas A-20 twin engined attack aircraft. Equipped with radar and painted black, it was designated the P-70. The P-70 was not a great success as a night fighter, largely because it was too slow to have much chance of catching speedy enemy aircraft. A night-fighting version of the P-38 Lightning was also built in

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limited numbers. With an extra seat for the radar operator behind the pilot and a radar pod under the nose, it was a capable night fighter. And as mentioned previously, small numbers of F6F Hellcats and F4U Corsairs had radar sets installed to act as night fighters. These conversions were only stop-gap, however, until a more potent replacement could enter service.

With the evidence of the early stages of the war in Europe, the Air Force concluded that a purpose-built night fighter would be necessary, and in 1940 Northrop was contracted to build one. This would become the largest American fighter of the war, and the only purpose-built Allied night fighter, the P-61 Black Widow. The name of the plane came from the factory applied coat of glossy black paint and red stencil markings. Although development was slow, eventually over 700 P-61s served in both Europe and the Pacific. In Europe the P-61 operated in an intruder mode, flying missions at night to destroy enemy trains, supply depots, troop concentrations and other tactical targets. In the Pacific, P-61s operated alone, patrolling specific sectors during the night hours. Any other plane encountered was automatically hostile, and engaged. Despite being larger than many medium bombers, the P-61 was fast, maneuverable, and heavily armed. It was very successful in both the night interceptor and night intruder roles, having good range and the capacity for carrying considerable external ordinance.[5]

Despite the success of the P-61, the increased performance capabilities of the upcoming generation of jet aircraft, both fighters and bombers, forced the Air Force to consider the need for a replacement. North American's P-82 Twin Mustang was selected as a temporary replacement for the P-61. Designed in 1943, the P-82 looked like two P-51D Mustang fuselages joined by a short central wing section, although it was actually an entirely new design. Originally intended as an ultra long-range escort fighter, with a pilot and a secondary pilot/navigator, it was eventually

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equipped with a large radar pod hung under the central wing and used as a night fighter. The F-82 continued in service into the early 1950s, with the first American aerial kills in Korea being scored by F-82s based in Japan. It was obvious even before the end of the World War II, however, that something more would be needed.[6]

Even as the war in the Pacific continued, the Air Force devised specifics for a new "All Weather" fighter, and in late August 1945 invited aircraft companies to submit design proposals based on those specifics. Those specifics, usually referred to as GORs (General Operational Requirements), included the following:

> Class - High performance fighter, capable of diversified operations in all kinds of weather.
>
> Mission - The destruction of enemy air forces and of tactical targets under all weather, day and night conditions.
>
> Performance -
>
a)	High speed at 35,000 feet	525 mph
b)	High speed at sea level	550 mph
c)	Climb to 35,000 feet	12.5 minutes
d)	Combat radius of action at 10,000 feet	600 miles
	at best operational altitude	1000 miles

> Automatic Rocket Fire - ... a rocket installation completely housed within the aircraft capable of automatically firing high velocity rockets which are suitable for air-to-air and air-to-ground combat shall be developed.
>
> Guns - ... Guns will be flexibly mounted so as to provide 15 degrees of movement in any direction from the longitudinal axis of the airplane. ... A minimum of four forward firing guns and two rearward firing guns is required. Aircraft should be designed and constructed to permit the interchangeability of installation between caliber .50 or comparable guns, and the 20mm cannon.
>
> Ground Attack Installations - Provisions are required for the installation of a minimum of two bombs in all standard sizes up to

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> 1,000 lbs. Provisions shall also be made for the installation of a minimum of eight rockets.
>
> Crew - Pilot and radar observer. [7]

One interesting characteristic of these requirements is that they do not specify jet engines, leaving the choice of the power plant up to the designer. Also, the beginning of the Air Force's attraction to missile armament can be seen in the desire for a automatic rocket fire.

In the post-war world of slashed budgets and canceled contracts, any invitation to submit proposals for a new design would be certain to attract a great deal of interest from aviation companies. No less than six firms submitted design proposals for this set of GORs, and one of the firms, Northrop, actually submitted four separate proposals. Recognizing the virtual impossibility of meeting the strict performance criteria with piston engines, all nine of the proposed designs were jet powered.

The six companies that submitted designs to the Air Force were Bell, Goodyear, Douglas, Northrop, Convair, and Curtiss-Wright. Goodyear quickly dropped out, unable to compete due to post-war cutbacks, while Bell and Convair decided to concentrate scarce funds and reduced staff on other projects. Bell was working on their XP-83 penetration fighter at that time, and Convair decided to concentrate on producing their giant B-36 bomber and developing their futuristic XF-92 delta-winged interceptor. This left Douglas, Curtiss-Wright, and Northrop in the running.[8]

The Douglas design, the XF3D Skynight, had been created for a similar role with the Navy, and the company hoped to expand the market for the plane to the Air Force as well. Curtiss-Wright had been working on developing a jet powered attack aircraft for the Air Force,

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the XA-43. That project was canceled due to a change in Air Force requirements in its very early stages, and Curtiss-Wright shifted the funds and personnel to the new all-weather project. Several secondary sources have asserted that the resulting design, the XP-87, was a modified version of the XA-43, but this is not true. The XP-87 was actually an entirely new and different aircraft, and simply used the funds and resources that had been originally made available for the earlier XA-43 project.[9]

The four Northrop proposals were essentially two basic designs, each presented twice, with modifications. The first of these designs was a fairly conventional, straight-winged jet fighter, while the second was a swept-wing, tailless design, strongly influenced by the earlier XP-79 project. In both cases, the primary difference between the two was the type and number of the engines. The first version of each design would be powered by two TG-180 engines, while the second was to be powered by three Westinghouse C-24 engines. Of the four Northrop design proposals, the first - straight-winged with two engines - was selected for testing as the XP-89.[10]

One area that prompted considerably discussion during the early development of the new all-weather fighters was the exact role intended for the aircraft. One school of thought was that an all-weather fighter was the same as a daylight air superiority fighter, such as the P-80, P-84, or P-86, only with radar, and should be able to conduct all normal fighter missions during daylight as well as radar-guided missions at night. The other position was that the intended target of the all-weather fighter was ultra-long-ranged strategic bombers, and that the chance of encountering enemy fighter escorts was extremely remote.

Those advocating the first view took the position that the all-weather fighter should be capable of performing any task as well as a daylight penetration fighter, and, along with its other

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missions, should be able to engage in combat with such daylight fighters with a high probability of success. This would mean that the all-weather fighter should be, to use a modern expression, a multi-mission aircraft. Those holding the second view argued that the only real purpose of the all-weather fighter was to destroy large bombers, and that the aircraft should be optimized to perform that mission, even if it meant sacrificing capabilities for performing other tasks. As the United States had not had to use night fighters in a major defensive role before, there was no institutional experience on which to draw to judge between the two concepts. But gradually the second view, of the all-weather fighter as a specialized bomber destroyer, came to prevail. This eventually resulted in a revision of the GORs for the all-weather fighter, with the result of removing the requirements for a forward turret, rearward armament, and external ordinance capacity. Forward firepower, however, was to be increased.[11]

Development of all three prototypes proved to be a lengthy process. The Air Force requirements were quite demanding, especially given the relatively limited power of the available jet engines and the limited capacities of the early radar sets. It would be almost three years from the issuing of the GORs to the flight testing of the first prototypes. In July 1947, the Air Force amended the GORs for the all-weather fighter as noted above, demanding even higher standards of performance. The amended portions of the requirements were, in part:

Performance -

a)	High speed at 50,000 feet	700 mph
b)	High speed at sea level	700 mph
c)	Climb to 50,000 feet	15 minutes
d)	Combat radius of action at 10,000 feet	1,000 miles
	at best operational altitude	1,500 miles

Armament -

b) Guns - A minimum of two forward firing rocket guns is

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required.

> Guided Missiles - Consideration shall be given to the installation of air-to-air and air-to-ground guided missiles.[12]

The first of the new prototypes to be completed was Curtiss-Wright's XP-87. The first XP-87 left the factory on 9 November 1947, headed by truck to Muroc for flight testing. Although in many respects a thoroughly conventional straight-winged design, the XP-87 had a number of unusual features which Curtiss-Wright hoped would give it an edge in performance over its rivals from Northrop and Douglas. One of these innovations was to seat the pilot and radar operator side by side, rather than one behind the other, as was the standard practice with two seat fighters. Although this option gave the radar operator much better visibility, it also made the fuselage very wide. Curtiss-Wright used that feature to advantage by using the fuselage as the primary fuel storage location. That extra fuel storage room was necessary, due to another unusual element of the XP-87's design.

The decision had been made to power the XP-87 with four Westinghouse J34-WE-7 engines developing 3,000 pounds of thrust each. These engines were located in rectangular nacelles on each wing, two to a nacelle. Even in the beginning of the XP-87's design life, these engines were somewhat underpowered, as the prototype was initially planned to weigh almost 40,000 pounds. These engines were chosen because they were designed to run off of gasoline, rather than the standard jet fuel, kerosene. Gasoline was lighter than kerosene, but the rate of fuel consumption was higher, necessitating additional fuel storage space. So the extra fuselage space was needed for the design.[13]

Another interesting feature of the XP-87 was that it was originally designed to have a

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bomb bay in the fuselage. This was an attempt to fulfill the original requirement that the plane be capable of carrying ground attack ordinance, including up to 2,000 pounds of bombs. The P-87 was originally intended to be an all-around tactical airplane, capable of providing ground support during inclement weather. This was an attempt to adhere to the original specifications for an all-weather fighter, first issued on 23 November 1945: "The prime consideration was the prevention of a recurrence of the 'Battle of the Bulge' during which tactical air support for ground troops was lost due to weather conditions. The XF-87 was therefore conceived as an offensive fighter capable of seeking out and destroying enemy aircraft and ground targets in all weather conditions day or night."[14] When the decision was made to optimize all-weather fighters for bomber interception, the bomb bay and the tail turret were removed from the design.[15]

Curtiss-Wright considered the nose turret, designed to house four 20mm cannon, the most innovative element of the XP-87. Studies and mockups indicated that the turret would allow for gunfire up to 60 degrees from the nose centerline, with the guns being aimed by radar. This would give the XP-87 a degree of combat flexibility that its large size might otherwise deny it.[16] However, when the prototype first flew, the actual turret was still under construction by a subcontractor, and even a simulated turret was unavailable. As a result, the XP-87 did its flight testing with a simple nose cone in place of the intended power turret. While the first XP-87 was beginning flight testing, a second prototype was under construction at the factory. This would allow Curtiss-Wright to make any changes due to problems discovered during the flight testing.

The initial flight of the XP-87, on 1 March 1948, was uneventful, although the plane had relatively high takeoff and landing speeds (150 and 140 mph, respectively) and required a lengthy takeoff run (over 6,000 feet). The high ground speeds during taxi and flight tests were also hard

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on the tires, causing them to lose almost all of their tread. The weight of the prototype had continued to increase, and the weight of the XP-87 at takeoff was over 42,000 pounds. One problem experienced during this first flight was a strong buffeting at speeds above 220 mph. This buffeting would prove to be difficult to overcome, and would be a major obstacle in the XP-87's development.[17]

Following additional test flights, a number of things became obvious about the XP-87. Its takeoff characteristics remained marginal, and the buffeting, although diminished, was never eliminated. Later takeoff runs and speed were reduced somewhat, but still remained high. In performance, the plane met or exceeded most of the original requirements for an all-weather fighter, although not the more recent revised specifications. Top speed was 556 mph at 15,000 feet and 525 mph at 30,000 feet, which very nearly matched the original GORs. Rate of climb was actually superior to the original GORs, at 3,950 feet/minute at sea level and 2,200 feet/minute at 20,000 feet. Range was not tested, although fuel consumption figures indicated that the XP-87 would have the desired range, as well as the capacity for carrying external fuel tanks.[18]

During the flight tests, Curtiss-Wright submitted a request for an official name for the XP-87, which was approved. Curtiss had been producing fighters for the Army Air Force since the 1920s, and most of them used the word "Hawk" in one form or another. Various Hawk, Sparrowhawk, and Super Hawk biplanes were followed by the P-35 Hawk monoplane and the P-40 Tomahawk/Warhawk. Continuing this raptor legacy, the XP-87 became the Blackhawk.[19]

As a result of these tests, a number of recommendations were made for altering the second prototype, still under construction. One decision was to increase the wing area from 600 square feet to 740 square feet and add split flaps, in an effort to eliminated the buffeting problem.[20]

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Another was to modify the plane to allow it to conduct photo reconnaissance missions.[21] Finally, in an effort to improve performance, the decision was made to replace the four J34 engines with two J33-A-29 engines with afterburners, producing 5,900 pounds of static thrust, with 7,500 pounds of thrust available with the afterburners.[22]

Although the performance of the XP-87 prototype was barely adequate at best and it possessed a number of problems that promised to require a significant amount of time and money to overcome, the Air Force's perceived need for all-weather fighters caused them to contract for 88 production P-87s during the early stages of the XP-87's flight testing. Fifty-eight of these production machines were to be the standard fighter models, and 30 of them were to FP-87 photo reconnaissance aircraft. Delivery of these machines was to begin in January 1950, and conclude one year later. Given the problems already known about the XP-87, and others certain to appear during further evaluations, to call this delivery schedule overly optimistic is being kind - wishful thinking is a more accurate description.[23]

The XP-87 was not the only all-weather aircraft under development at this time. Northrop's XP-89 was also progressing, and would make its first test flight a short time after the XP-87. The XP-89 used the more conventional placement of the radar operator behind the pilot, but like the XP-87, it had a number of unusual features. The two J35-A-13 engines (3,800 pounds of static thrust) were mounted on the bottom of the fuselage, where their air intakes would not interfere with the fuselage streamlining. The engines were mounted on hydraulic mounts, which extended the engine out of the airplane for service and replacement. This was a considerable benefit to maintenance crews, especially given the short life of the early jet engines. Like the XP-87, the XP-89 was originally intended to have a remote turret in the nose to carry the

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armament, although this requirement was deleted during the design process.[24]

The XP-89 used a very thin straight wing, enabling it to get some of the high speed advantages of the swept wing without any of the low speed penalties. The wing was mounted in the middle of the large fuselage, which meant that it was high enough off the ground for a tall man to walk under without ducking. This in turn dictated that the landing gear would look rather unusual. The double-wheeled nose gear was very short, while the two wing-mounted main wheels were very large and very narrow. The need to fit the tire into the thin wing dictated a narrow wheel, and the height of the wing called for a large tire to keep the gear legs from becoming dangerously long. This resulted in a tire that was almost four feet in diameter, but less than a foot wide. This frequently prompted the crews of the airplane to remark that the tires looked as though they had been taken from a farm tractor.[25]

In September 1946 the Air Force examined the mockup of the XP-89, and was not impressed. There were a great many things the Air Force wanted changed, and all work on the prototype was halted while the changes were being made. One of the most important things they wanted changed was the location of some of the fuselage fuel cells. These had been placed over the hottest locations on the engines, which the Air Force felt had the potential for danger even in normal operations, and certainly could be catastrophic in the event of combat damage. They also wanted changes in the cockpit, oil system, and wings. Northrop had wanted to make considerable use of magnesium in the wing design, for strength and reduced weight. Mindful of both the flammable potential of magnesium and the increased cost, the Air Force told the company to use aluminum instead. In December of the same year the revised mockup was inspected, and although some additional changes were requested, work resumed on the prototype.[26]

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The original XF-89 prototype finally took to the air at Muroc on 16 August 1948. Although the first flight was aborted early because of a hydraulic leak, it was otherwise uneventful. Like the XF-87, the XF-89 was underpowered and therefore slower than originally hoped for, but early flight tests revealed no serious problems.[27] During these early tests, the XF-89 received its name, first as a nickname and then with official sanction. The upswept tail with its high horizontal stabilizer reminded everyone (especially in the desert climate at Muroc) of a scorpion poised to strike, and the name stuck. The name had the additional benefit of continuing the concept of poisonous arachnid names for Northrop aircraft begun with the P-61 Black Widow.[28]

As the early flight tests of both the XF-87 and XF-89 revealed that both had mediocre performance at best, the Air Force decided to have a "fly-off" contest to evaluate each aircraft, as well as the Douglas XF3D Skynight. The tests were to be conducted by experienced night fighter pilots, radar operators, and maintenance personnel, and the results would then be evaluated by senior Air Force officers as well as the flying and maintenance crews. These flight tests were held on 6-7 October 1948, with interesting results.[29]

In cockpit arrangement and seating the XF-87 was best, with the XF3D placing second and the XF-89 last. Ease of maintenance went to the XF3D, with the XF-87 in second and the XF-89 again last. In fact, the XF-89 placed last in most categories of evaluation. The overall winner of the competition was the XF3D, with the XF-87 coming in second.[30]

These results were then placed before the Committee on Evaluation of the XF-87, XF-89, and XF3D Aircraft (as the testing group was known officially). Comprised of eleven voting and twelve non-voting members, the committee made the following recommendations: 1) unanimous

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votes were cast against procuring either the XF-87 or the XF3D, 2) there were unanimous votes in favor of procuring a radar-equipped version of the Lockheed TF-80C as an interim night fighter, and 3) there was a seven-to-four vote in favor of procuring the XF-89.[31]

These results are interesting for a number of reasons. The unanimous rejection of the XF-87 was based on the conclusion that the airplane would require a major redesign in order to become an effective combat aircraft. The unanimous rejection of the XF3D is harder to explain. Although a large, ungainly, and modestly performing design, as were the other two aircraft, it had been the clear winner of the competition and the Navy had already contracted for its construction. Perhaps the rejection of the XF3D was more of an institutional attitude on the part of the Air Force than an objective measure of the aircraft's capabilities. Although the Air Force and Navy have routinely tested each other's aircraft since the 1920s, from that time to the present only two aircraft designed for the Navy have been adopted and widely used by the Air Force - the McDonnell F4 Phantom, and then only after demonstrating clear superiority over the best fighter in the Air Force at the time, the Convair F-106 Delta Dart; and the Douglas AD-1 Skyraider, a single-engined ground attack aircraft, adopted largely because the Air Force did not posses an effective ground attack aircraft of its own.[32] The Navy, however, has proven willing to use aircraft designed for the Air Force, if such aircraft can be demonstrated to fulfill Navy requirements. Such crossover aircraft include many Curtiss biplane fighters in the 1920s and 30s, the Consolidated B-24 Liberator and North American B-25 Mitchell bombers during World War II, and North American's F-86 Sabre in the late 1940s and 50s.

The committee's reluctant recommendation of the XF-89 can be seen in the mixed vote. Despite the Air Force's urgent need for an all-weather interceptor and the elimination from

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consideration of two of the three evaluation aircraft, the fact that four of the eleven members of the committee voted against procuring the only remaining aircraft was an indication of its marginal performance. The overall ranking of the XF-89 in last place in the evaluation no doubt contributed to this outcome. Despite its poor showing in the various categories, however, most of the committee members considered that the XF-89 did have one thing in its favor - it was seen as being the most capable of performing the combat mission it was designed for. It was also considered to have more potential for development than either of the other two aircraft.

Perhaps the most interesting action taken by the committee was one that went beyond its charge to evaluate the three planes. That was the decision to recommend procurement of an interim all-weather interceptor, based on the proven Lockheed F-80 design. The committee felt that since the one aircraft it had evaluated and could recommend would likely require several additional years for development before it could become operational, a stop-gap replacement was needed. Since the F-80 already existed in a two place version (the TF-80C, put into production earlier in the year), it was felt that it would prove a relatively simple matter to modify the plane to accept a radar system and utilize it in an all-weather role.

The recommendations of the committee were followed in all particulars. The initial contract for 90 F-87s (2 XF-87s and 88 production models) was canceled, with an addendum about changing procurement policy so that prototypes would be fully evaluated before placing any production orders. The cancellation of this contract effectively forced Curtiss-Wright out of the aircraft manufacturing business. The single XF-87 continued to be tested, and the nearly completed second prototype used as a source of spare parts to keep it flying. Proposals for interim night fighters were solicited from both Lockheed and North American, to develop radar-

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equipped versions of existing aircraft.[33]

In November 1948, the Air Force asked Lockheed for two prototypes of a radar-equipped interceptor version of its TF-80C aircraft, and also placed a preliminary order for 150 production models of the same aircraft. In January 1949 North American was officially asked to develop an interceptor version of the F-86, initially designated the XF-95. Also, on 10 January 1949, the Air Force officially contracted for 48 production F-89s and 110 F-94As (as the new Lockheed interceptor was designated).[34]

Flight testing of the XF-89 continued. No serious problems were encountered, although the airplane was obviously underpowered, which gave it disappointing performance characteristics. On 27 June 1949 the XF-89 suffered an accident involving one of the main landing gear legs, and required a significant amount of time before returning to full flight status. Test flights resumed on 15 October 1949, and continued until 22 February 1950, when the XF-89 was destroyed in an accident. Investigation revealed that the turbulent airflow created by the exhaust from the engines had set up low frequency vibrations in the tail of the aircraft, which separated from the rest of the plane in flight. This accident killed the flight engineer in the radar operator's seat, and severely wounded the pilot. All production of the F-89 was halted until the cause of the accident was determined and corrected.[35]

A second Scorpion prototype was built by Northrop, with the designation YF-89. This aircraft was completed in December 1949 and accepted by the Air Force in January 1950. Following the crash of the XF-89, it was grounded to await the results of the investigation and for rebuilding to incorporate design changes that would appear on the production machines. The most important change was the installation of more powerful J35-A-17A engines with

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afterburners. Later the YF-89 would be given the still more powerful J-35-A-21. The increased power available from the new engines produced significant improvements over the original underpowered prototype in most of the performance categories of the YF-89. Top speed increased from 562 mph to 610 mph, take-off distance decreased from 6,780 feet to 1,960 feet (fully loaded), and time to climb to 35,000 feet decreased from 24 minutes to 4 minutes.[36]

Other changes to the YF-89 included auxiliary blow-in doors on the engine nacelles for extra air flow on the ground and at low speeds, cooling ducts for the engine fans and afterburners, slimmer permanently attached tip tanks to replace the more bulbous jettisonable ones on the XF-89, and a redesigned nose section. The original nose, intended to house a remote turret, had been short and blunt. The new nose was several feet longer, slender and tapered. It was intended to hold six fixed 20mm cannon in the lower section and the radar system above the cannon. Finally, as a result of the investigation of the crash of the XF-89, exhaust deflectors were fitted to the fuselage immediately behind the engine, and mass balances were added to the tail surface. The heavily modified aircraft, now designated the YF-89A, resumed flying on 27 June 1950.[37]

Two prototypes of the YF-94 (there were no 'X' versions of the plane because it was a conversion of an existing type) were converted from the initial production batch of twenty TF-80Cs. The major changes between the trainer and the interceptor version were the addition of an APG-33 radar and Hughes E-1 fire control system, housed in a redesigned and lengthened nose, and the addition of a J33-A-33 engine with an afterburner. The modified aircraft was almost 2,000 pounds heavier than the TF-80C, and the afterburner was needed for increased speed. The addition of the afterburner necessitated enlarging the rear of the fuselage, producing a much fatter looking rear section to the new plane. In addition to the radar, the YF-94 carried four Browning

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M3 .50 calibre machine guns in the nose. Despite the added weight, the more powerful afterburning engine gave the YF-94 superior performance over both the TF-80C and the original F-80C single seat version. Top speed increased from 580 mph to 606 mph.[38]

Because the modifications to the TF-80C were relatively minor (save for complications with the radar and fire control systems), the YF-94 prototypes were completed quickly. The first of the two prototypes flew on 16 April 1949, and the second on 1 July 1949. Both of these planes had few problems during test flights, and as the F-94 showed the potential for earlier delivery to the Air Force than the F-89, its production was to be expedited. The first of the F-94A production machines would be accepted by the Air Force in December 1949.[39]

The last entry into the all-weather competition was a proposal from North American to modify their high performance F-86 for all-weather duties. The initial North American concept had been conventional for an interceptor, with the addition of a second seat for a separate radar operator. Studies indicated that such a project would require a major redesign of the airplane, and would impose substantial penalties on its performance, despite the addition of an afterburner to the engine. So the engineers at North American came up with a more radical concept - keep the new version a single seat aircraft, and include sophisticated radar, fire, and engine control systems to handle various tasks for the pilot and to allow him to concentrate on his combat mission. It would be this concept the company would develop when asked for an all-weather interceptor by the Air Force.[40]

Work on the two YF-86D prototypes began on 28 March 1949. The interceptor version of the F-86 was initially designated the F-95, but was redesignated the F-86D prior to any production models being finished. Several changes were made to the standard F-86 for the new

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version. The new engine, the J47-GE-17, produced 7,500 pounds of thrust with its afterburner. To avoid distracting the pilot with the need to coordinate throttle and afterburner controls, an automatic system for the various fuel controls was developed. Despite an increase in total weight, the new engine gave the F-86D outstanding speed, and several new speed records were set by the aircraft, with one of 715.6 mph being recorded in 1953.[41]

The addition of the APG-36 radar set and Hughes E-3 fire control system necessitated some redesign of the fuselage. The radar was located in a large, bulbous nose cone, requiring a modified and lowered airscoop beneath it. The fuselage was deepened to accept the afterburning engine. Perhaps the most radical change was the replacment of the gun armament with a retractable ventral tray carrying twenty-four 2.75 inch FFAR "Mighty Mouse" rockets. When the pilot pressed the trigger, the tray would extend, fire, and retract automatically. The pilot could fire six, twelve or all twenty- four rockets in a volley.[42]

The modifications to the basic F-86 airframe were not drastic, and were completed relatively quickly. What delayed the development of the F-86D were the new electronics systems. The first examples of the Hughes fire control systems were found to have all manner of defects, many attributed to sloppy construction techniques - mixed-up connections, defective parts, and even the occasional tool left inside! Also, these new systems, while very advanced and sophisticated by the standards of the day, were still quite large, delicate with their vacuum tubes and electric wiring, trouble-prone, and maintenance intensive. When they worked properly, they were very effective. When they malfunctioned, which was often, the whole aircraft was rendered useless for its primary mission. Both of the prototypes did much of their flight testing without their electronics systems, neither being fitted with the Hughes fire control.[43]

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While flight tests and evaluations continued on the various all-weather prototypes, work continued on the production versions of these aircraft. Delays continued to plague all the programs, and none of the companies were able to deliver aircraft by the original contract dates. The F-86D program, in particular, ended up almost three years behind schedule.

When the XF-89 was destroyed in the crash in February 1950, all work on production machines was halted until the cause could be found and a fix put in place. The first three production machines, designated F-89As, were virtually finished at that point, and so were completed and accepted by the Air Force as test aircraft. Production did not resume until December of the same year. The next five aircraft, also F-89As, were delivered in March 1951, and also served largely as test aircraft.[44]

The remainder of the initial production order, forty aircraft, were designated F-89Bs, and had a few changes made to them. The jet wake fairing, added to deflect the exhaust stream away from the tail, had been retrofitted to the A models, and became a standard feature starting with the Bs. The B models also had three large and heavy mass balance horns, often called ice tongs from their appearance, added to each horizontal stabilizer to help dampen vibrations as well.[45]

Some additional minor modifications produced the F-89C. 164 aircraft of this type were produced. Incremental improvements in engine power and reliability began during the production of the F-89C, with minor improvements to performance and maintenance. The external mass balance horns of the B model were replaced by internal balances on the C. The F-89C also dispensed with the ability to carry external ordinance, relying solely on its six 20mm cannon. The first of the F-89Cs were delivered in September 1951.[46]

In March 1952, an F-89C disintegrated in the air and crashed. Although increasingly

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severe restrictions were placed on the operation of all F-89s, five more such accidents occurred over the next six months. The final accident was witnessed by a large audience at the International Aeronautical Exhibition in Detroit, Michigan. Following this accident, all F-89s were grounded pending a thorough investigation.

Study of the accidents revealed that their cause was essentially the same problem that had affected the early model P-84s. The shape of the wingtip tanks was producing a twisting effect during flight maneuvers, inducing greatly increased stress on the wing structure, which lead to the sudden and catastrophic separation of the wing from the fuselage. The fix involved strengthening the wing spar and fuselage connection, and adding small fins to the outer rear of the wingtip tanks. These measures were also retrofitted to previously produced aircraft.[47]

The accidents should never have occured, however. Four years before, a series of similar accidents with the F-84, also a straight-winged jet fighter with horizontally mounted tip tanks, had led to the discovery of the same forces and problems, and simple measures for prevention of similar accidents. The accidents with the F-84 occured even before the XF-89 began its test flights, and were events that both Northrop and the Air Force officers associated with the F-89 program should have taken note of. The major refit of the YF-89 after the crash of the XF-89 would have been an ideal time to incorporate the relatively simple fixes to prevent a similar situation occurring with the F-89. The basic similarity between the external shape of the two designs - straight-winged fighter with horizontally mounted tip tanks - should have at least prompted some concern over whether similar accidents were possible with the F-89. But a thorough investigation was not done until six F-89s had disintegrated in flight. By way of contrast, when Lockheed's F-94 was modified to carry horizontal tip tanks, the small stabilizing

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fins were added as a matter of course, preventing any such accidents.

By the early 1950s, with the Soviet Union in possession of at least limited nuclear capability, the Air Force became increasingly concerned about their ability to destroy incoming bombers before they were able to release their weapons. By this point, the Air Force had apparently reached the conclusion that guns were obsolete as aircraft armament, and had embraced the concept of the guided missile as an effective means of destroying enemy planes. Unfortunately, the first generation of guided missiles were still in the test phase, so the Air Force, if they wanted aerial missiles, would be forced to rely on unguided rockets. The urge to ensure the destruction of enemy bombers was so strong that all interceptors would from this point forward have their gun armament replaced with rockets. The fact that an aircraft so equipped could fire its weapons at most three or four times before using up all of its ammunition was a distinctly secondary concern.

For the F-89, this meant the removal of the six 20 mm guns from the nose and their replacement with an extra fuel tank and a new fire control system. The primary change to the airplane was the replacement of the two streamlined wingtip fuel tanks with larger combination wingtip fuel tanks/rocket launcher pods. The rear of each of the new combination pods contained the same 300 gallon fuel tanks as the earlier models, while the forward portion held fifty-two 2.75 inch FFAR Mighty mouse rockets. This gave the plane a total of 104 rockets as its armament. These rockets could be fired all at once, or in up to three salvos. This modification became known as the F-89D, and a total of 682 of them were built.[48]

Improvements continued to be made in the Scorpion's engines, eventually culminating in the installation of the J35-A-35 engine. Shielding certain temperature sensitive elements of the

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engine also finally cured the F-89's tendency to lose power above 30,000 feet, and the airplane finally had a reliable and effective powerplant, which would remain the same on all further variants.

Eventually, the first generation of air-to-air guided missiles became operational, and the F-89 was modified to use them. The wingtip combination pods were further modified to carry three GAR-1 (later AIM-4) Falcon guided missiles. These missiles were carried in recessed and covered bays in the front of the pod, and were extended for firing. Although much rocket capacity was given up to carry the missiles, the pod could still carry 21 of the FFAR rockets, giving the plane a total weapons capacity of six Falcons and 42 FFARs. Both radar and infrared guided versions of the Falcon could be carried. This version became the F-89H, and 156 of them were produced.[49]

The final version of the Scorpion, the F-89J, took the missile overkill philosophy to its ultimate extreme. The combination wingtip pods were replaced with large 600 gallon fuel tanks, and all ordnance was carried externally, on hardpoints beneath the wings. The weaponry of this version was four of the Falcon guided missiles and two of the new AIR-2 Genie missiles. The Genies were larger than the Falcons, and had a new feature - nuclear warheads with a 1.5 kiloton yield. On 19 July 1957, for the first and only time, a live Genie was test fired from an F-89J and detonated 18,000 feet over Yuca Flats, New Mexico.[50]

Although they were the final plane in the series, the F-89Js were not the final production version of the airplane - the F-89H was. All 350 of the F-89Js were converted from the final production blocks of the earlier F-89D. As a result, all F-89Js had the capability of carrying the combination fuel/rocket wingtip pods, although this was almost never done operationally. In

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addition, the Falcon missiles proved to be extremely unreliable when carried externally. In a time before printed circuits and microchips, the Falcon used regular electric wiring and vacuum tubes. Carried externally at high altitudes, moisture invariably got inside the missile and shorted out the electronics, rendering the missiles useless. So most F-89Js carried only the two Genie missiles.[51]

The F-89 was never a very successful aircraft. Although some of its aircrew liked the plane as a stable flying platform, many thought it seriously underpowered and sluggish. It was often referred to as the "runway sweeper" or "vacuum cleaner" because its low-slung air intakes had a disturbing tendancy to suck up any debris on the taxiway or runway, which did unpleasant things to the engines.[52] Most critically, its low speed and limited service ceiling sharply restricted its effectiveness as an interceptor. Although capable of effective intercepts of piston powered bombers such as the B-29/B-50/Tu-4, the F-89 proved to be largely helpless to stop jet powered bombers. Even the B-36, once jet engines were added to it, was faster than the F-89 at altitude, and all-jet bombers, such as the B-47 Stratojet and B-52 Stratofortress were both faster than the F-89 and capable of operating far above the F-89's maximum altitude. Although the F-89 remained in service with Air National Guard units through the mid-1960s, it is probably a good thing that the airplane was never tested in combat.[53]

The second all-weather interceptor, the Lockheed F-94, had a much easier time entering production. The first F-94A production models were delivered to combat units on 26 May 1950, following a few earlier machines that had been used for testing purposes. As the entire F-94 project had been initiated in November 1948, this was rapid progress indeed, especially by the standards of all-weather interceptors. All 110 of the F-94As were accepted by the Air Force by December 1950.

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The Air Force and Lockheed had planned to move directly from production of the F-94A to a considerably improved and reworked version, initially designated the F-97. The F-97, although similar in appearance to the F-94 and deriving from it, was in many respects a totally new airplane. All of the new systems proved to be troublesome, and slowed the development of the F-97 considerably, creating a need for an interim version of an interim aircraft. This temporary version would be known as the F-94B. The advent of the Korean War prompted the Air Force to redesignate a number of their aircraft, and the F-97 became the F-94C. The F-94C was given the name "Starfire", becoming the first of the F-94s to have an official name, although the name was often used for all versions of the airplane.

The F-94B differed little from the F-94A. The only obvious physical change was the substitution of horizontally mounted tip tanks for the underwing tanks of the F-94A. There were a number of internal changes, including a high pressure oxygen system, improved hydraulics and a Sperry Instruments "Zero Reader," a device that combined the functions of many instruments into two simple displays, and made possible effective combat instrument-only flying. Although instrument flying, that is, flying in conditions of limited visibility by concentrating solely on the instruments, had been done with larger airplanes, the Zero Reader finally made it practical on a smaller fighter, especially in the chaotic conditions of combat. One hundred and fifty F-94Bs were ordered by the Air Force in March 1950. In 1951, the Air Force ordered an additional 206 F-94Bs. These later aircraft were designated F-94B-5s, because they included factory installed deicing and defogging gear for the cockpit, wings, and tail surfaces.[54]

Problems with the various new systems of the F-94C delayed the program by almost two years, with the first production models reaching operational units in March 1953. Deliveries

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continued until May 1954, with a total of 387 produced.

The primary change between the earlier F-94A/B and the F-94C was the deletion of the machine guns in the nose and their replacement with twenty-four 2.75" FFAR rockets. All the rockets were placed around the nose of the plane, in three curved launcher panels of eight tubes each. In the center was the radar installation. To fire the rockets, small doors in front of the tubes retracted inward, creating a clear path for the rockets. Later examples of the F-94C would also have small rocket pods attached in the center of each wing. Firing the nose rockets often led to problems. Firing a partial volley could cause a compressor stall, and firing all twenty-four could cause a complete engine flameout. Further, firing all the rockets simultaneously produced such a dense cloud of exhaust gasses that the crew was unable to see until it cleared.[55]

Another major change in the F-94C was the powerplant. The new J48-P-5 engine developed 8,300 pounds of thrust with afterburner. The new engine had more power on the normal setting than the earlier engines did on afterburner. This new engine helped compensate for the increased weight of all the modifications to the airframe, and performance continued to improve.

Other changes included new thinner wings, with much greater dihedral (the angle at which the wings bent up from the horizontal) than earlier models. There was a new Hughes E-5 fire control system, with much more power (250 kw compared to 50 kw) than earlier units. The horizontal tail surfaces were swept back, and later machines also had a drag chute for landings in a bulged fairing above the exhaust outlet.[56]

The F-94, especially the C model, was more effective than the F-89 as an interceptor, and in 1954 swept all the interceptor competitions at the Yuma Gunnery Meets.[57] Nonetheless,

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fulfilling its role as an interim model, the F-94 remained in service for only a relatively brief time. F-94As and Bs were all relegated to Air National Guard units by 1954, and the F-94Cs followed by 1957. By 1959, there were no F-94s in active service, either in the Air Force or the Air National Guard. F-94As and Bs did see limited combat service in Korea.[58]

The final interceptor of the period, the F-86D, was the last to get into production, and the latest to enter service. Nevertheless, it would become by far the most successful of the all-weather fighters, and be produced in far greater numbers than any of the others. Although flight testing of the prototype revealed some problems to be corrected, the primary difficulty was with the electronics systems. The Hughes E-3 system put in the first F-86Ds was late, and delivery of these thirty-seven aircraft was not complete until October 1952. The Hughes E-4 fire control for the majority of the F-86Ds was even more of a problem. In the winter of 1952-3, over 320 F-86D airframes were parked at the North American factory, awaiting the delivery and installation of their electronics.[59]

Delivery of the F-86D began in the spring of 1953, and as the electronics were finally debugged and installed, proceeded rapidly. The F-86D quickly became the most effective and numerous all-weather interceptor in the Air Force; eventually 20 of the 30 squadrons in Air Defense Command were equipped with F-86Ds.[60] The F-86D was not an easy aircraft to fly, however. In fact, it demanded more training and effort from the pilot than any other aircraft in the Air Force's inventory. A special school was set up specifically to train F-86D pilots to fly their planes effectively.[61]

One major change made during the production of the F-86D was the installation of the SAGE (Semi Automatic Ground Environment) system. This system linked the airplane directly to

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ground control equipment, allowing the pilot to read information directly from ground-based instruments rather than have to work through other human beings. This greatly increased the effectiveness of the weapons system. This new equipment, combined with other improvements at the same time, such as a new electrical system, produced a new designation, the F-86L.[62]

Over 2,504 F-86Ds were manufactured, and 827 F-86Ls. An export version, the F-86K, was built mainly for sale to NATO countries. License-built by Fiat, the F-86K featured simplified and more reliable electronic systems, and replaced the missile armament with four 20 mm cannon. 221 F-86Ks were built in total.[63]

The F-86D was the most effective and numerous of the all-weather interceptors, despite being a late adaptation of a single-seat fighter. The F-86D pointed the way towards the current generation of single-seat air superiority fighters, capable of operating in almost any weather and visibility conditions. It would serve in the Air Force and with NATO in Europe throughout the 1950s, until being replaced by the next generation of supersonic fighters designed with integral radar and fire control systems.

The all-weather fighters were developed to protect America against a perceived vulnerability to long-ranged strategic, and later nuclear, bombardment. With historical hindsight, it can be seen that the Soviet ability to deliver this sort of attack during this entire period ranged from non-existent to minimal. But the only measure to judge such capabilities available to the Air Force was its own SAC, which certainly was capable of making the sort of attack the all-weather interceptors were attempting to defend against. In the end, it was certainly more reasuring for the Air Force to have protected the country against a largely unrealized threat than to have taken no protective measures against the possibility of nuclear immolation of America's cities.

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6. Dorr, Lake & Thompson ***Korean War Aces*** pp .6-10.

7. Brigadier General Alfred R. Maxwell, Chief, Requirements Division, Office of Assistant Chief of Air Staff -3 to Assistant Chief of Air Staff - 4 "Military Characteristics of Aircraft (All-Weather Fighter)" 23 November 1945

8. Marty J. Isham & David R. McLaren ***Northrop F-89 Scorpion: A Photo Chronicle*** Atglen, PA: Schiffer Military/Aviation History, 1996, p. 7.

9. Both Steve Pace's ***Edwards Air Force Base*** and Isham and McLaren's ***Northrop F-89 Scorpion*** claim the XF-87 was derived from the XA-43. Also, from the XF-87 Case History - "The fact that the XF-87's were built under the original XA-43 contract gave rise to the erroneous opinion of many that the XF-87 was in fact the XA-43 with a new model designation. Actually the two airplanes were dissimilar in size, equipment and mission." "Chronological Summary of the F-87 Project" Entry 172, Box 63, Record Group 341, National Archives., abstract, p. 1.

10. Isham & McLaren ***Northrop F-89***, p. 7.

11. Brigadier General L.C. Cragie, Chief, Engineering Division to Research and Engineering Division, Assistant Chief of Air Staff, Washington. 7 June 1946 ***XF-87 Case History***.

12. "Military Characteristics of Aircraft (All-Weather Fighter)" 24 July 1947 Entry 172, Box 38, Record Group 341, National Archives.

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25. Larry Davis and Dave Menard ***F-89 Scorpion in Action*** Carrollton, TX: Squadron-Signal Publications, 1990, pp 4-5.

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30. Davis & Menard ***F-89 in Action***, p. 5.

31. Report on All-Weather Fighter Requirements, Conference at Muroc Air Force Base, Muroc California, 6 October 1948 ***XF-87 Case History*** The members of the committee who voted in favor of the XF-89 were Major General K. B. Wolfe, Major General F. O. Carroll, Colonel Albert Boyd, Lieutenant Colonel O. B. Johnson, Captain D. M. Dessert, Lieutenant F. J. Smith, and Lieutenant R. A. LeBeuf. The members who voted against the XF-89 were Brigadier General C. A. Brandt, Colonel B. K. Holloway, Lieutenant Colonel G. B. Timmons, and Major B. E. Turner.

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36. Ibid., p 23.

37. Kinzey ***F-89 Scorpion*** pp. 16-7.

38. McLaren ***Lockheed F-80***, p. 181; Isham & McLaren ***Lockheed F-94***, p. 120.

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40. Jackson ***F-86 Sabre,*** pp. 42-3.

41. Davis ***F-86 Sabre in Action***, p. 17.

42. Jackson ***F-86 Sabre***, pp. 44-5.

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44. Kinzey ***F-89 Scorpion*** pp. 18-21.

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47. Ibid.

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49. Ibid., pp. 46-8.

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53. Kinzey ***F-89 Scorpion***, p. 10.

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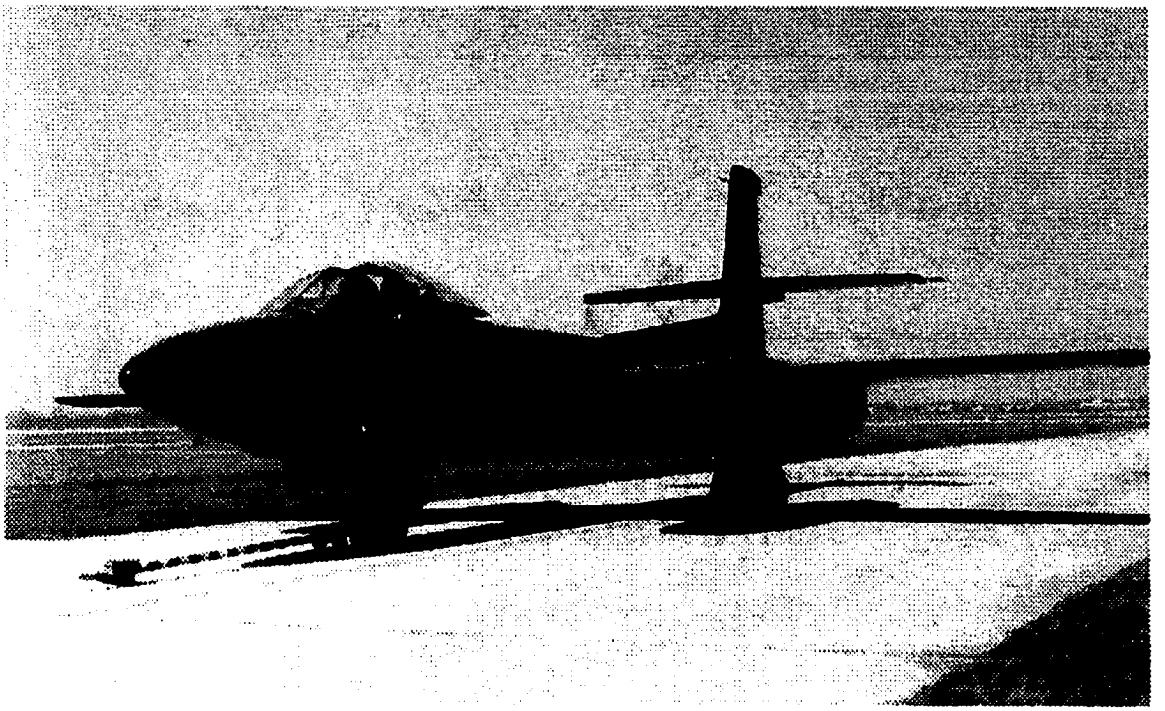
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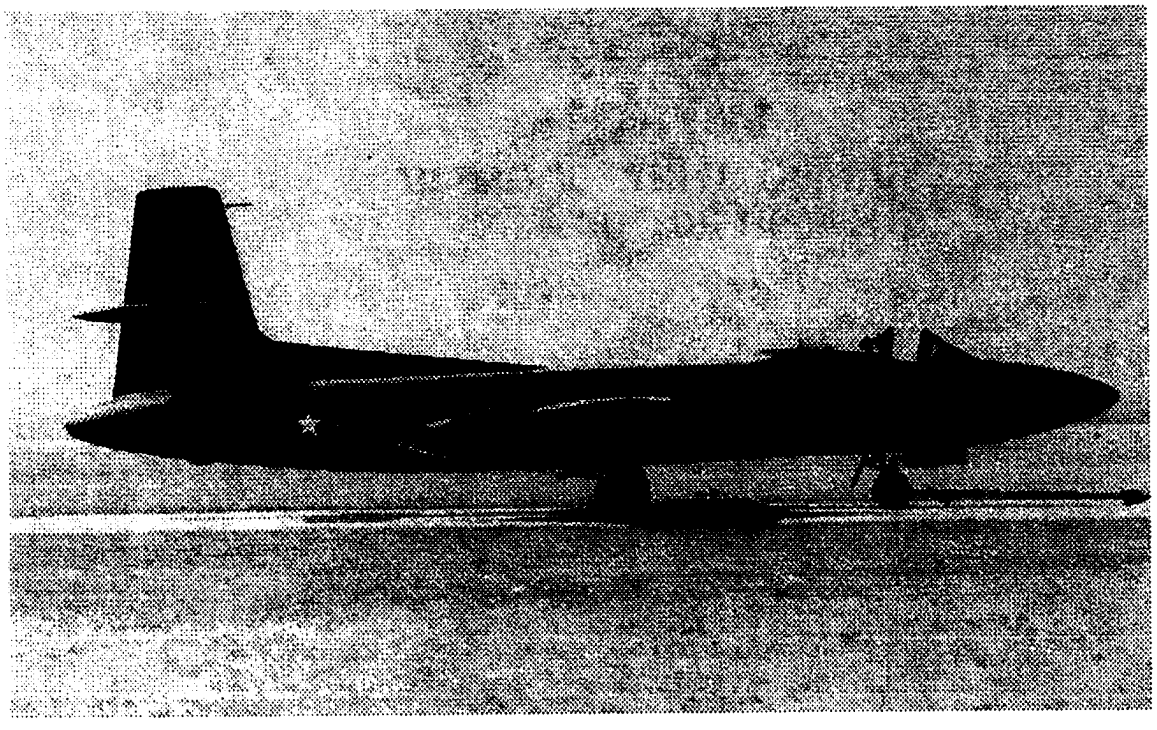
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The Curtiss-Wright XP-87. Photo credited to Wright-Patterson Air Force Base, dated 1 August 1949. (National Archives, Photographic Division, Box 2032, Number 30624)

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The XF-87 from the side. Photo credited to Wright-Patterson Air Force Base, dated 1 August 1949. (National Archives, Photographic Division, Box 2032, Number 30625)

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The XF-87 from the front. Photo credited to Wright-Patterson Air Force Base, dated 1 August 1949. (National Archives, Photographic Division, Box 2032, Number 30626)

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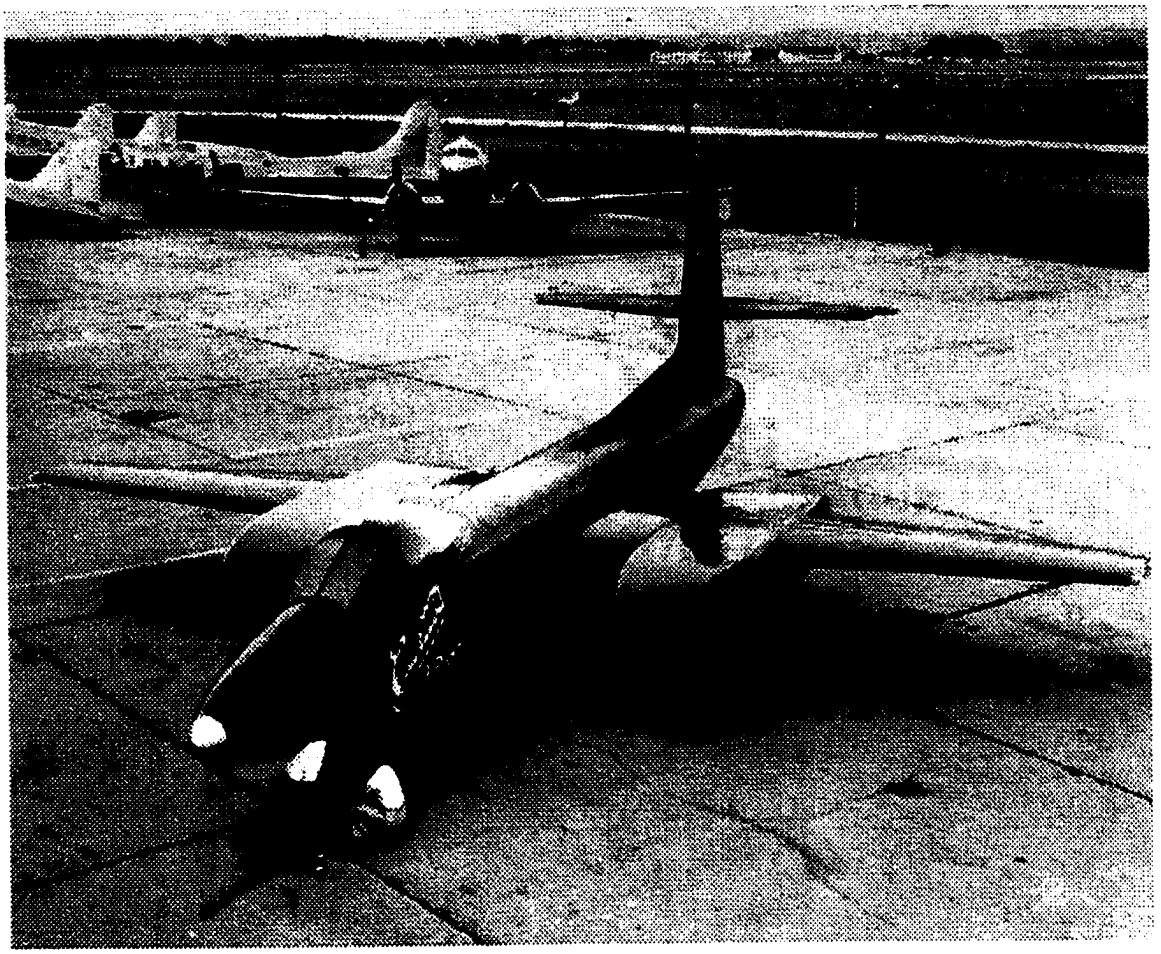
The XP-87 on its original roll-out from the Curtiss-Wright factory. The large size of the airplane is evident from the figure next to it. Photo credited to Curtiss-Wright, dated 3 September 1947. (National Archives, Photographic Division, Box 2032, Number 30628)

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The XP-87 on one of its early test flights at Muroc. The side-by-side seating of the crew can be seen in the cockpit. Photo credited to Muroc Air Force Base, dated 26 April 1948. (National Archives, Photographic Division, Box 2032, Number 30635)

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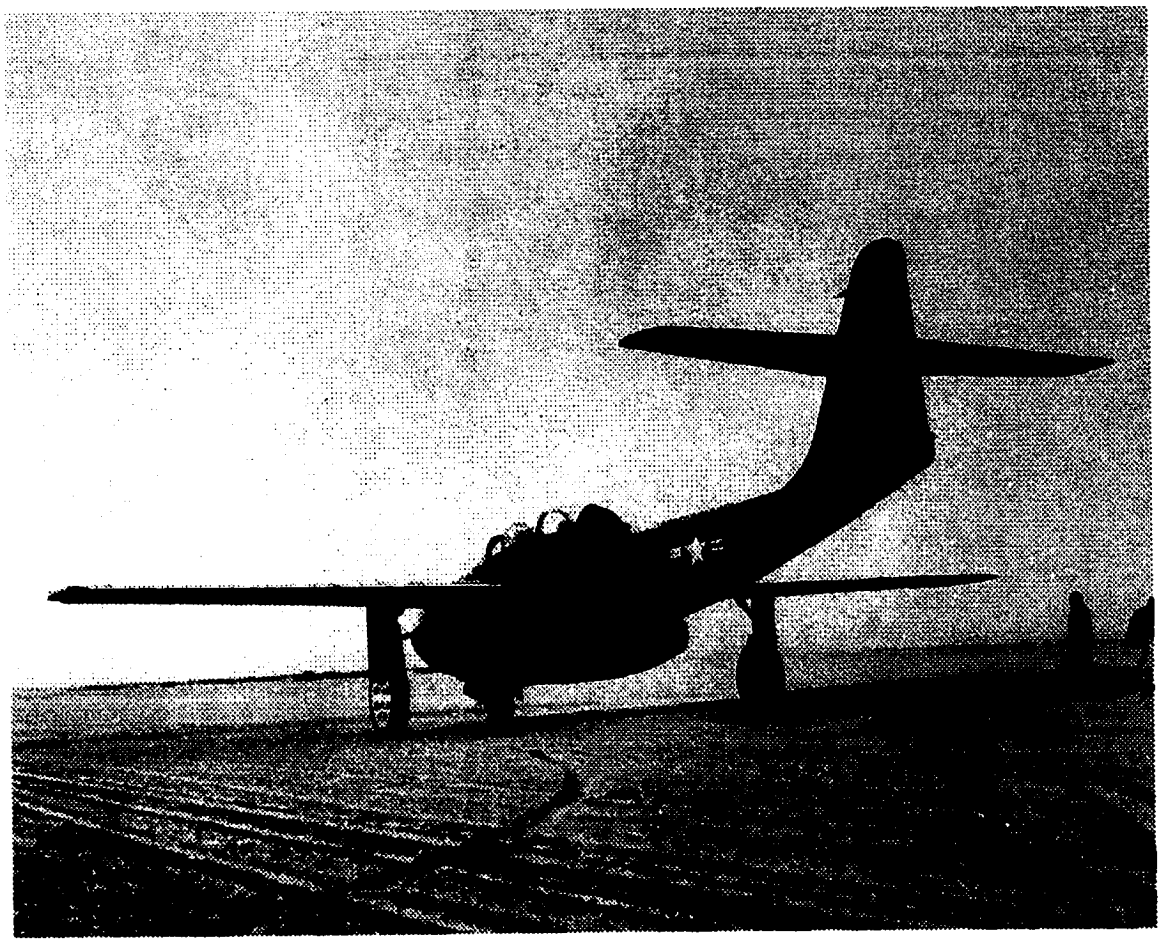
The XP-87 at the Curtiss-Wright factory. Of interest are the DC-3 airliners and the stripped-down B-17 in the background. Photo credited to Curtiss-Wright, dated 3 September 1947. (National Archives, Photographic Division, Box 2032, Number 30629)

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The XF-89 during the early stages of its test flying at Muroc. Photo credited to Air Force Office of Public Relations, dated 30 September 1948. (National Archives, Photographic Division, Box 2032, Number 30649)

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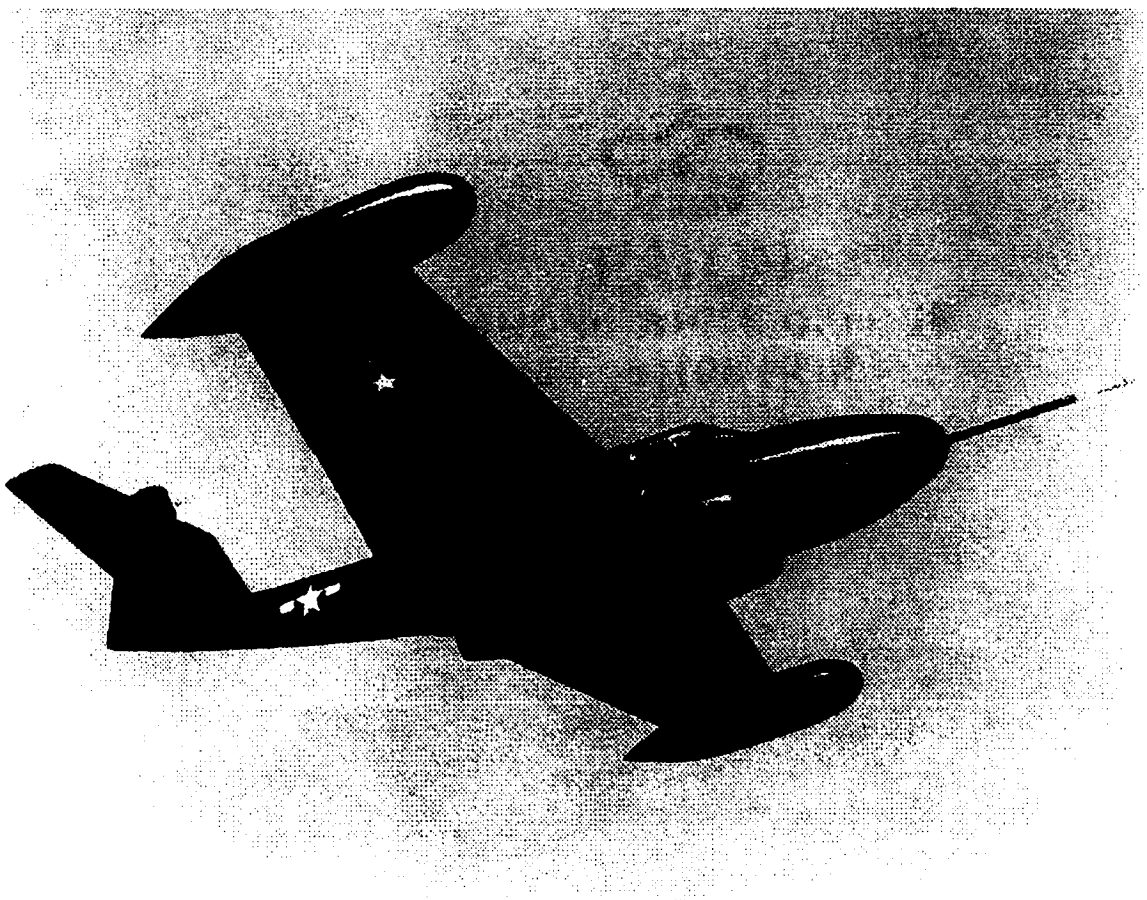
The XF-89 at Muroc. The high-swept tail that gave the plane the name "Scorpion" can be seen to good advantage in this shot. The size of the main landing gear tires can be seen in comparison to the figures at the right. The lack of wingtip tanks and an exhaust deflector on the fuselage can also be seen. Photo credited to Northrop Public Relations, dated 9 October 1948. (National Archives, Photographic Division, Box 3033, Number 30650)

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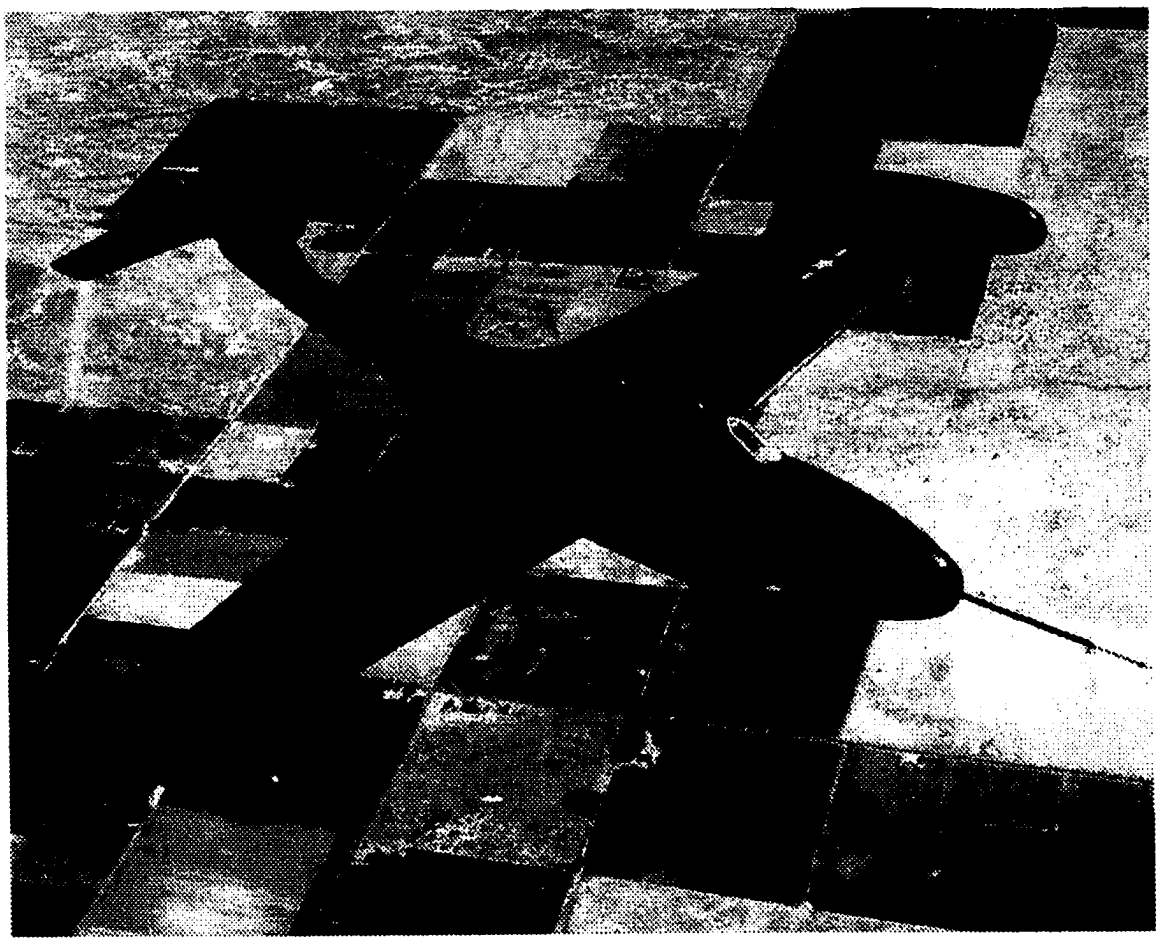
The XF-89 with various panels removed for maintenance. Photo credited to Northrop, dated 17 August 1948. (National Archives, Photographic Division, Box 2033, Number 30652)

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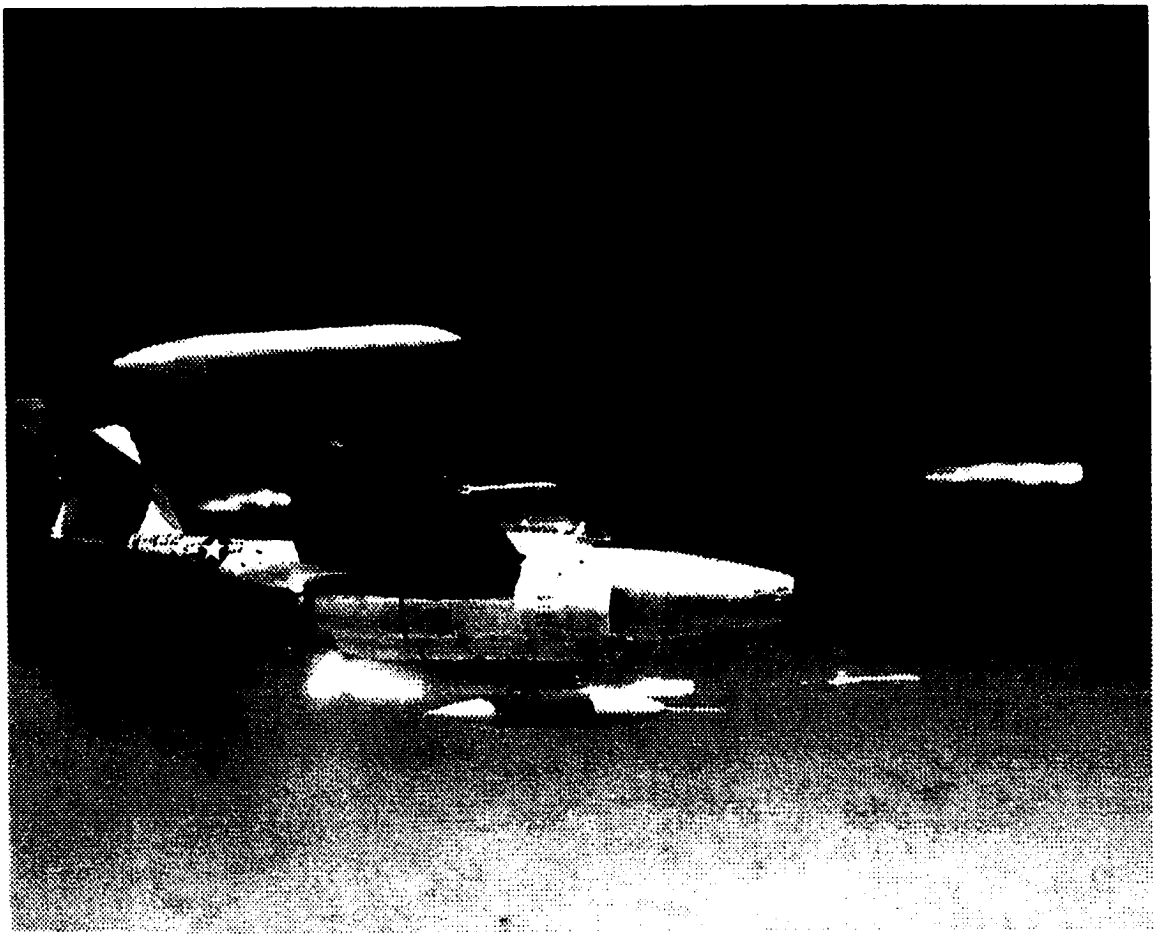
The XF-89 in flight, with the addition of wingtip fuel tanks. The broad wings and belly-mounted engines can be easily seen in this view. The long probe on the nose is for test instruments. Photo credited to Air Force Office of Public Relations, dated 3 November 1948. (National Archives, Photographic Division, Box 2033, Number 30654)

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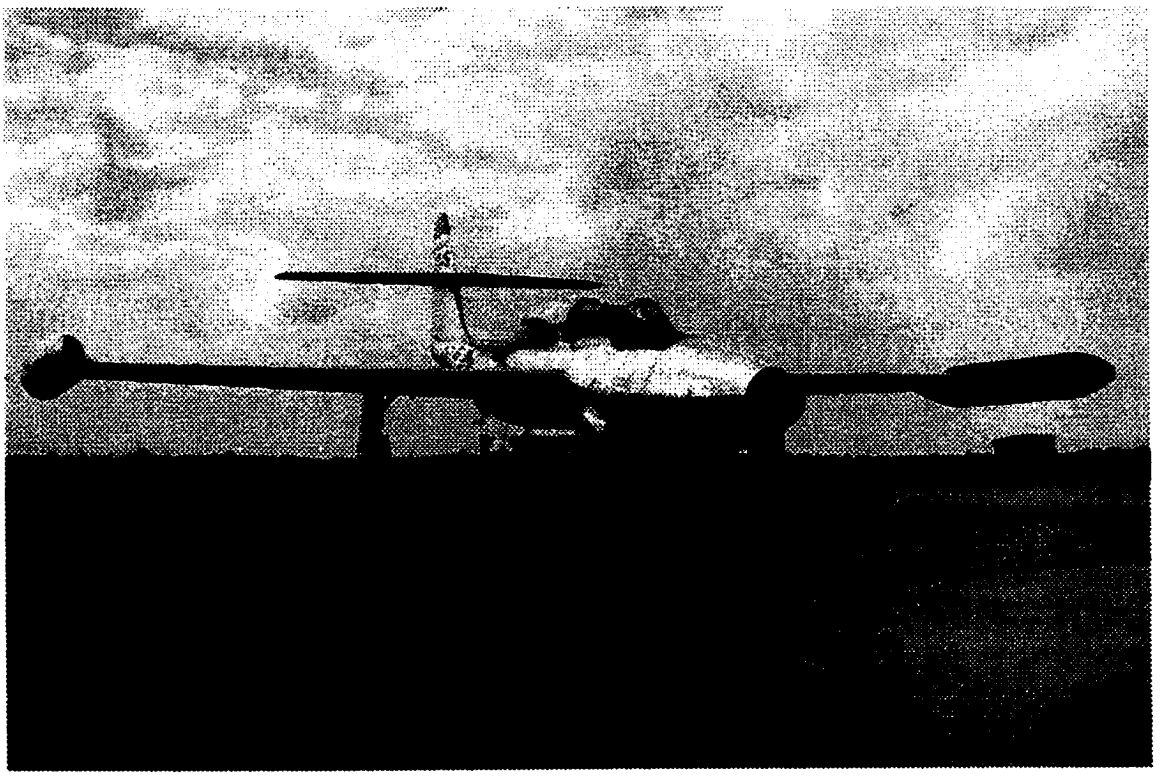
The XF-89 from above. The tandem seating arrangement for the crew can be seen in the cockpit. The sinister appearance of the prototype caused it to be cast in the role of a Soviet fighter in the Howard Hughes movie, ***Jet Pilot***, starring John Wayne and Vivian Leigh. Photo credited to Northrop, dated 14 April 1949. (National Archives, Photographic Division, Box 2033, Number 30656)

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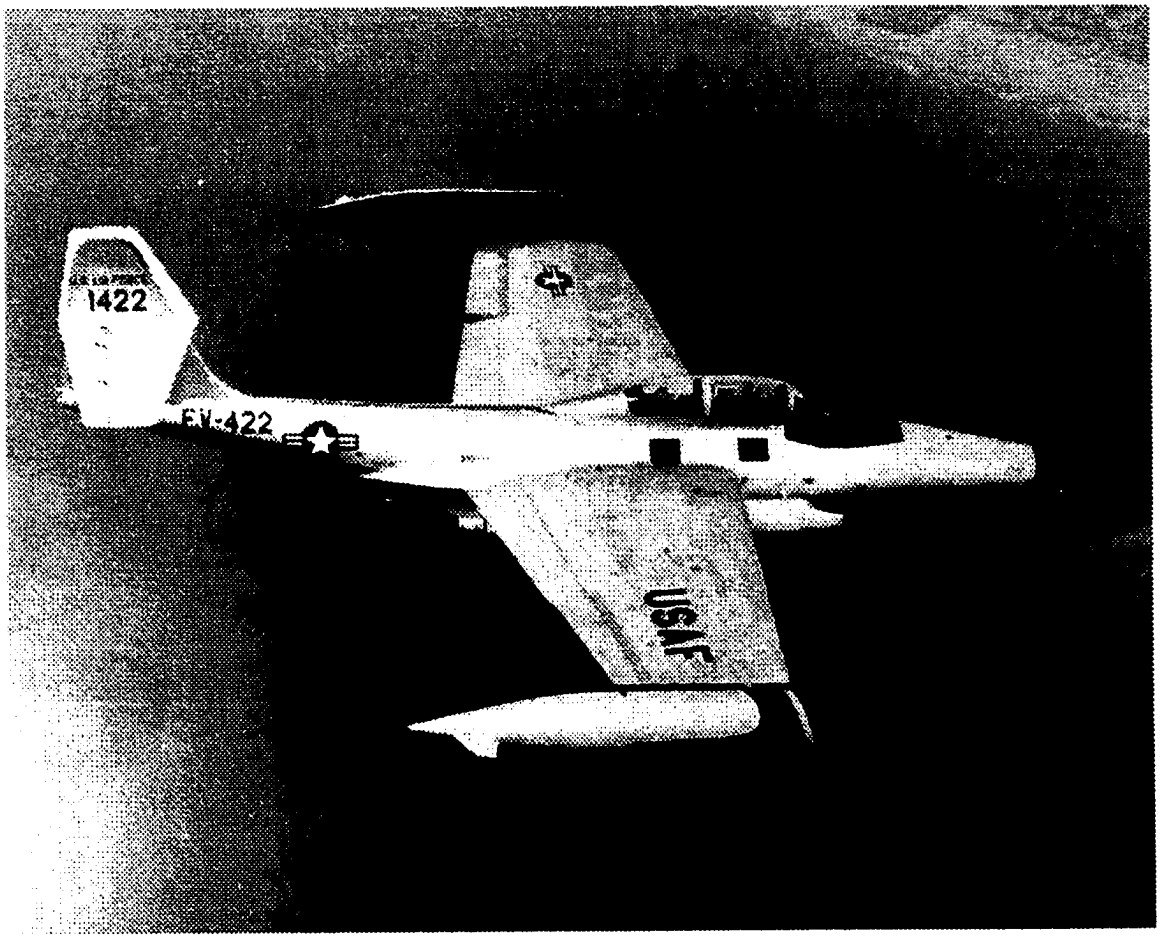
One of the first production F-89s, an F-89A test fires its 5" rockets. Note that this machine has been retrofitted with the mass balance horns on the horizontal stabilizers. Also note the much more slender tip tanks than those of the prototype. Photo courtesy of Northrop/Grumman.

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An F-89C, one of the cannon-armed versions. Note that the tip tanks lack stabilizing fins. The bulge on the bottom of the starboard engine nacelle is a fuel system purge generator, fitted only to early "C" models. Photo dated 5 February 1952. (National Archives, Photographic Division, Box 2033, Number 30667)

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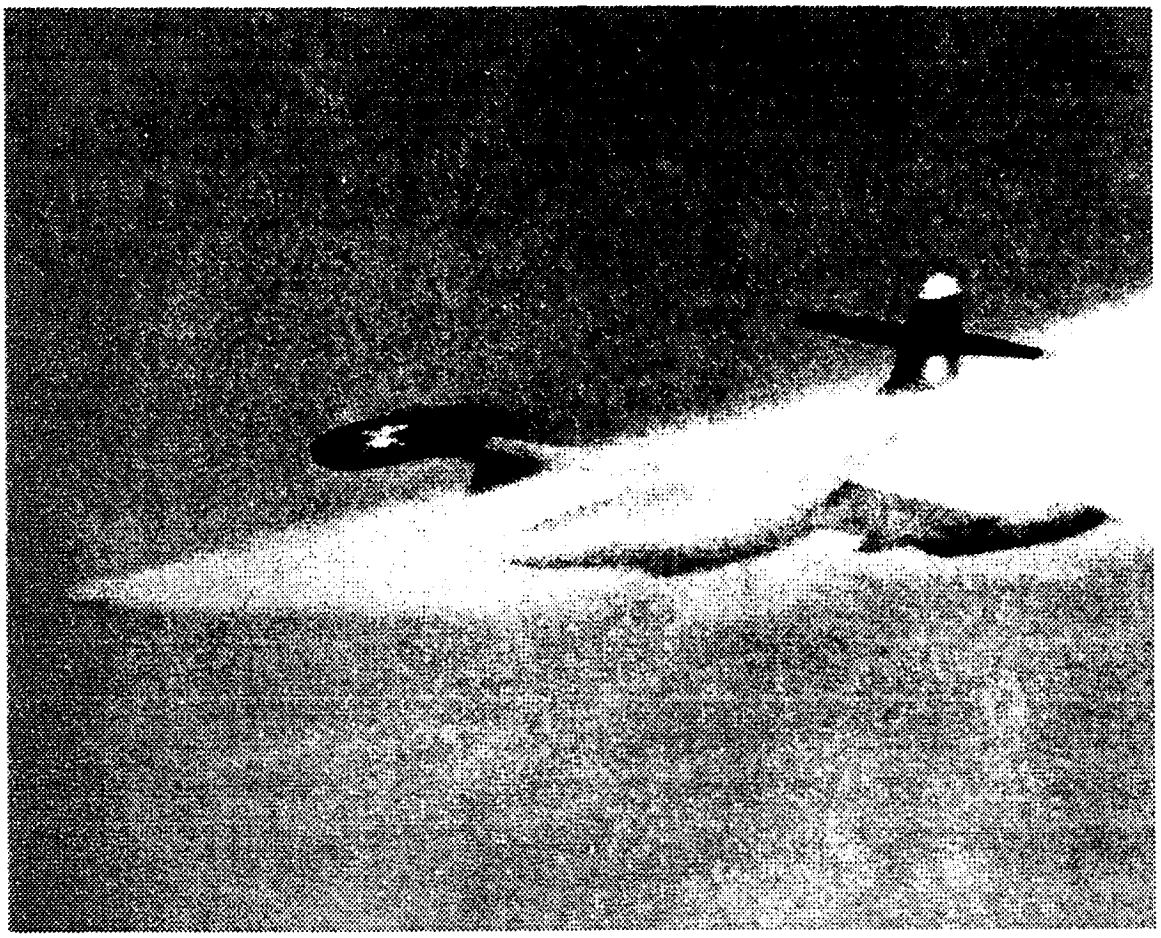
A rocket-armed F-89D. The large combination fuel tank/rocket pods, complete with the small stabilizing fins on the rear, can be seen on the wingtips. Note that the horizontal stabilizer protrudes in front of the vertical rudder. This was done to split the airlflow over the tail surfaces, which would otherwise cause turbulence and instability. Photo courtesy of Northrop/Grumman.

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An F-89D launching a salvo of 2.75" FFAR Mighty Mouse rockets on a test range. The Air Force promoted the F-89 as a fighter with the heaviest armament ever, 104 of the rockets. Photo credited to Air Force Office of Public Information, dated 10 July 1952. (National Archives, Photographic Division, Box 2033, Number 30684)

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Although of modest quality, this photograph nonetheless captures a moment of some historical significance. The original caption reads: "F-89J SCORPION -- (1957) -- FIRST NUCLEAR AIR-TO-AIR ROCKET FIRED.... A rare moment in history was captured over the lonely wastes of the Nevada desert by an Air Force cameraman when the first nuclear warhead air-to-air rocket left its launcher. The deadly rocket, known as the 'Genie,' was fired for the first time in July, 1957 from a Northrop Scorpion F-89J. Five members of the U. S. Air Force stood directly under the nuclear explosion to prove there was no danger of atomic 'fall out.'" The yield of a Genie was about 1.5 kilotons, and it was detonated about 18,000 feet over the desert. One wonders if there were any long-term effects for the five Air Force personnel standing below the aiming point. Photo courtesy of Northrop/Grumman.

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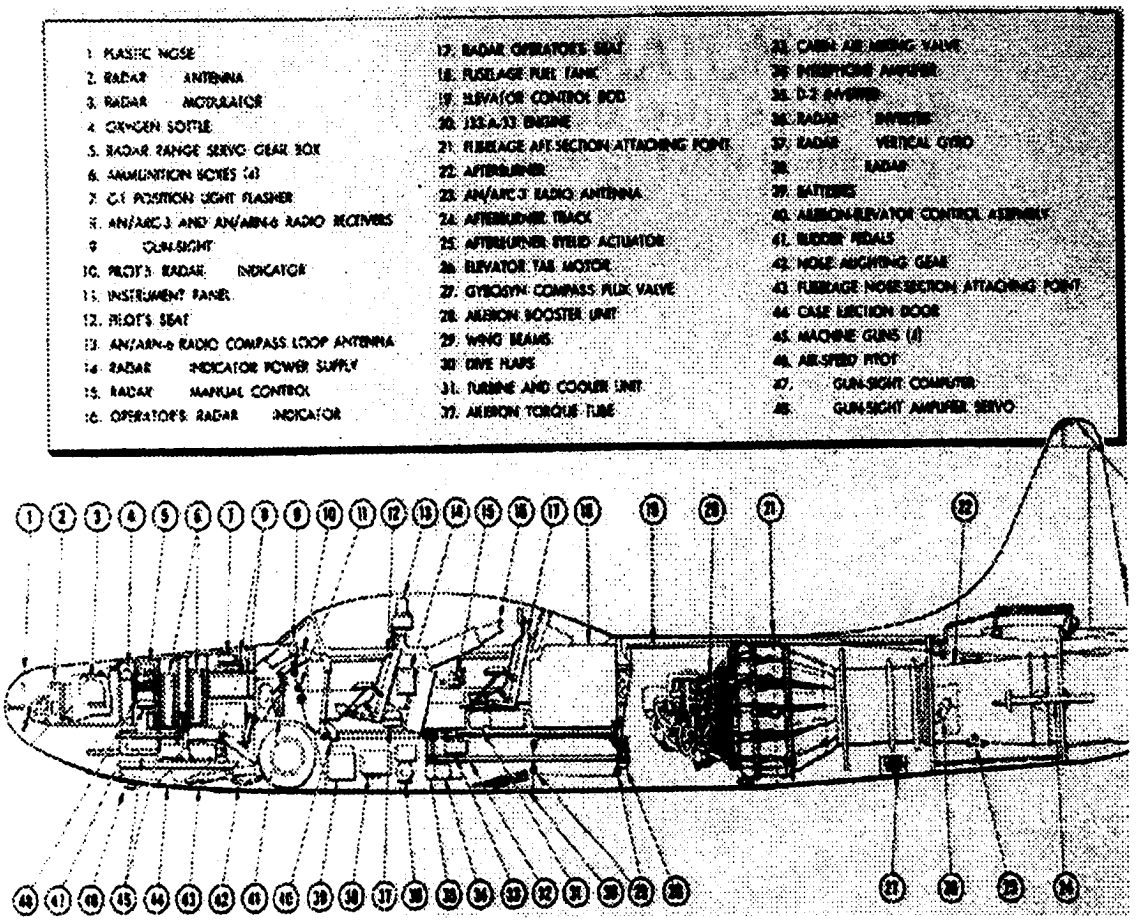
The original YF-94 in flight. This plane was originally an F-80C, the first to be converted to the TF-80C configuration. It later became the first converted to the F-94 configuration as well. Note the enlarged tailpipe, for the afterburner. Photo credited to Air Force Office of Public Relations, dated 27 June 1949. (National Archives, Photographic Division, Box 2033, Number 30776)

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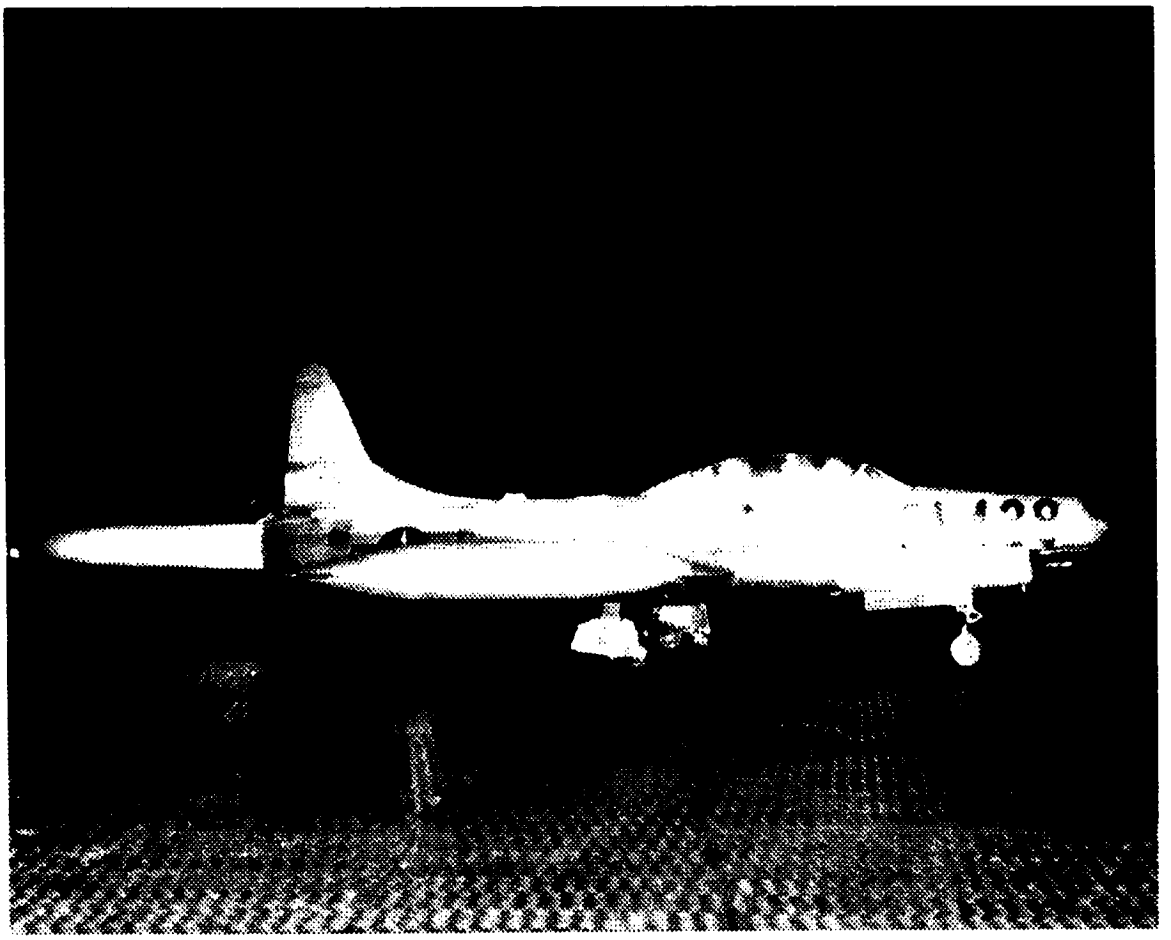
An F-94A belonging to the 449th FIS, based at Ladd Air Force Base in Alaska. Note the early style hanging tip tanks and the tarps on the wings and tail to prevent ice forming on them. The canopy is also slightly opened, to equalized temperatures and prevent frosting when the crew enters. The temperature was -50 degrees when this photo was taken. Photo credited to Ladd Air Force Base, dated 23 April 1952. (National Archives, Photographic Division, Box 2033, Number 30795)

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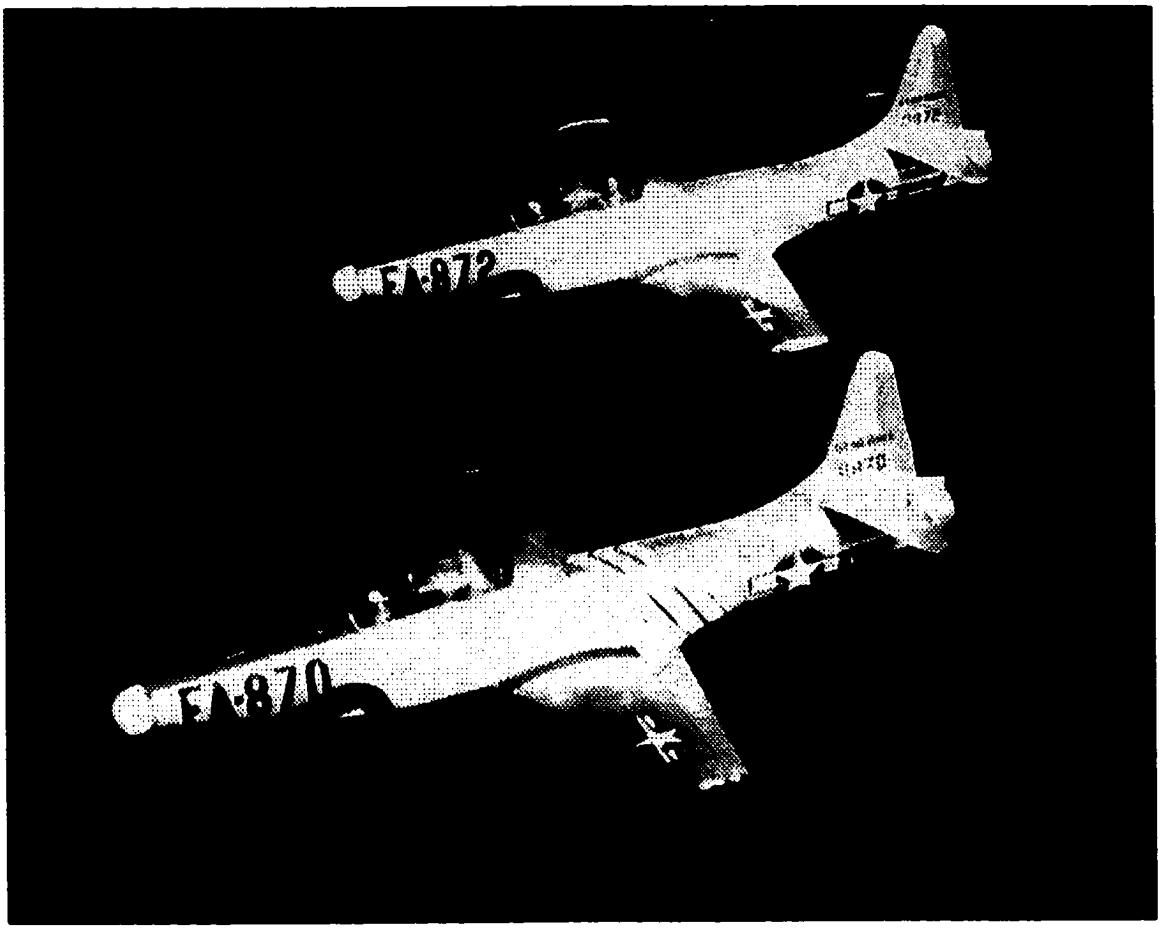
Cutaway diagram of an F-94. Photo credited to Department of Defense - Office of Public Information, dated 17 August 1950. (National Archives, Photographic Division, Box 2033, Number 30806)

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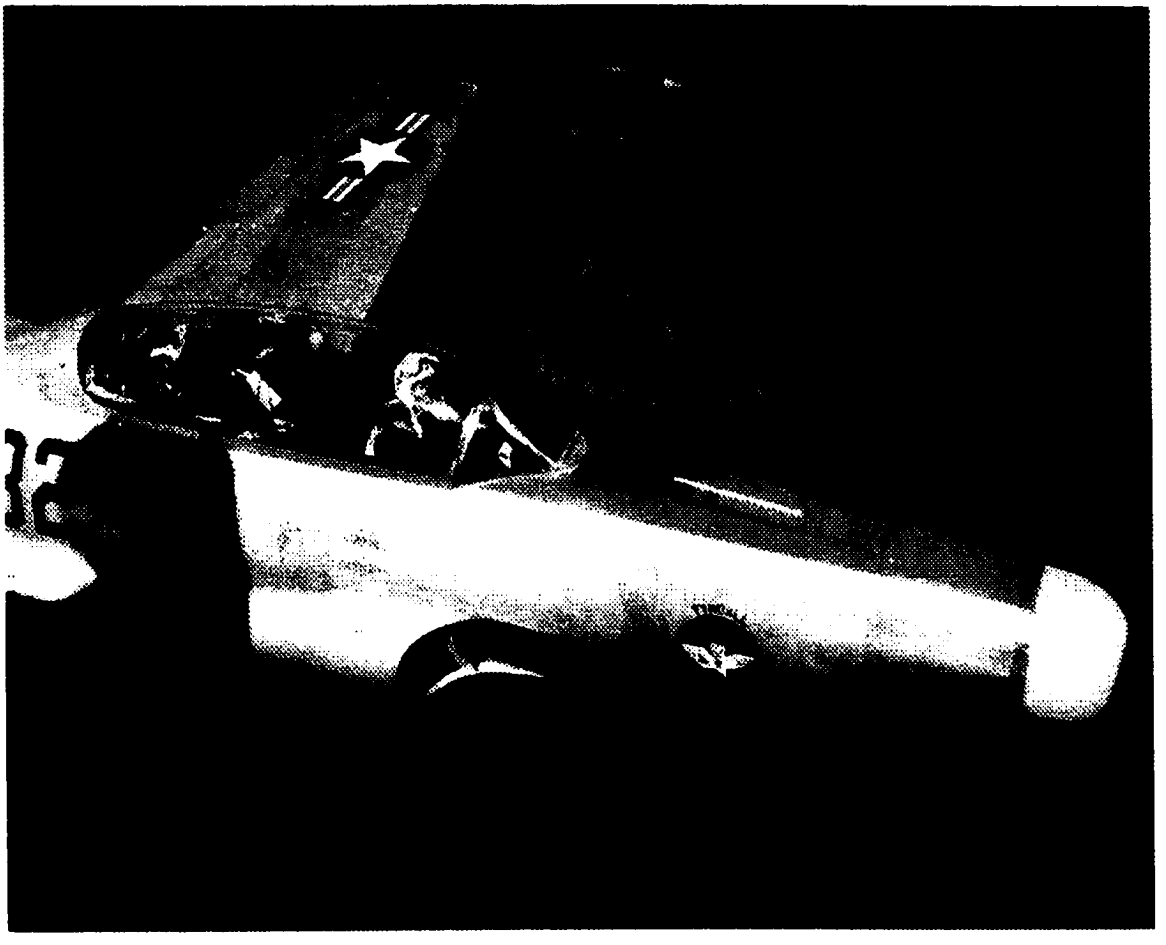
An F-94B running up its afterburner prior to take-off to hunt for North Korean night intruders. Photo credited to Far East Air Force, Korea, dated 20 March 1953. (National Archives, Photographic Division, Box 2033, Number 30807)

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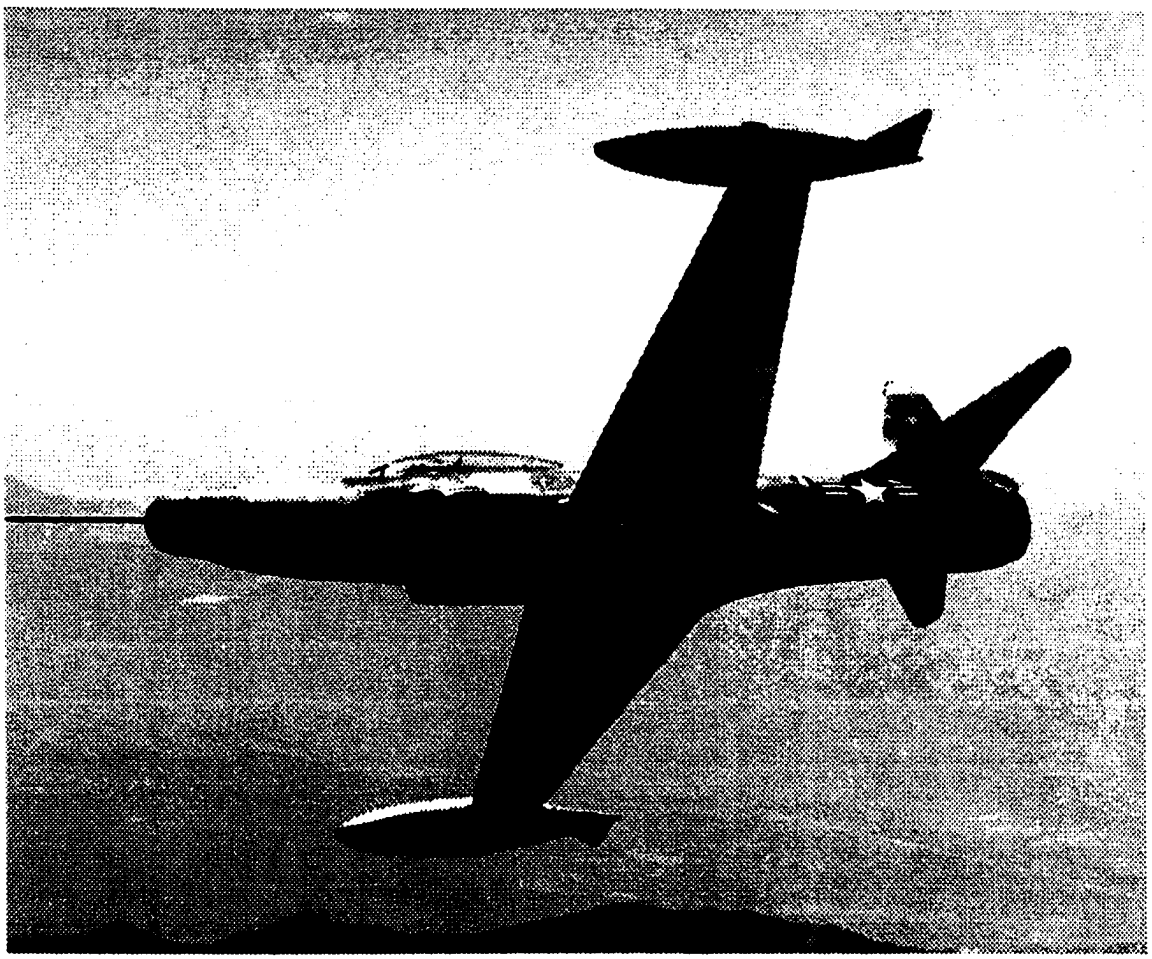
A pair of F-94Bs on patrol. Note that both aircraft lack tip tanks. Photo credited to Otis Air Force Base, Falmouth, Massachusetts, dated 19 September 1951. (National Archives, Photographic Division, Box 2033, Number 30817)

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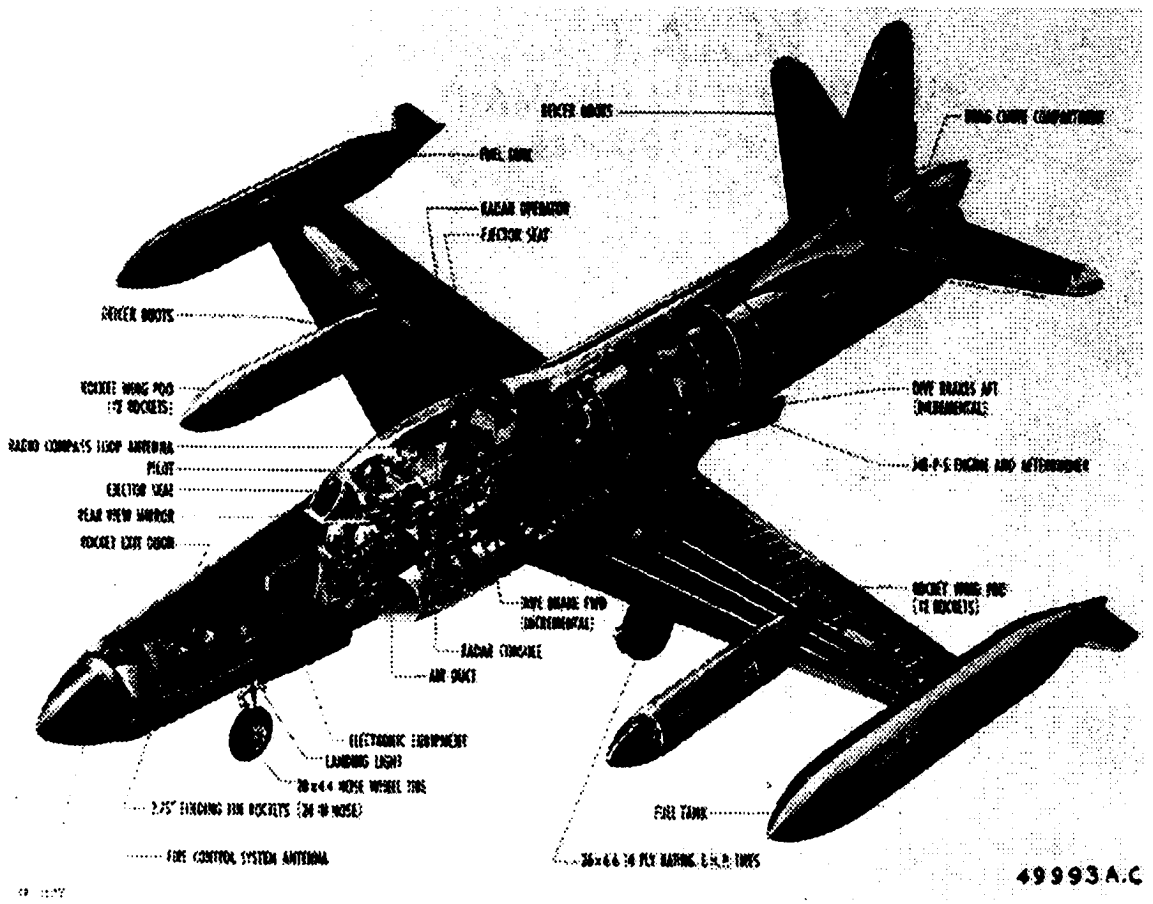
Close-up of an F-94B in flight from Tyndall Air Force Base, Panama City, Florida. The new horizontally mounted tip tanks with stabilizing fins can be seen on the port wing. Photo credited to Public Relations, dated 22 May 1952. Original caption reads "Crew Training in the Air Force: These men might well be the crews that shoot down an enemy aircraft before it unleashed its destructive A-bombs." (National Archives, Photographic Division, Box 2033, Number 30836)

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This is an F-94B, modified as the prototype of the YF-97 (later the F-94C) aircraft. The swept tail surfaces are a noticeable difference between this and the earlier F-94s. The long boom on the nose contains sensors for measuring pitch and yaw. Photo credited to Lockheed Corporation, dated 24 August 1950. (National Archives, Photographic Division, Box 2033, Number 30862)

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Cutaway diagram of the F-94C. Several of the changes from previous versions can easily be seen, including the swept tail surfaces, the rocket nose armament, and the wing-mounted rocket pods. Photo credited to Lockheed Corporation, dated 13 November 1953. Original caption reads "Starfires are on 24 hour duty - coast to coast - from the strategic San Francisco Bay region and manufacturing centers of Southern California to New York City and the heavy industrial areas of the Northeast and Atlantic Coast." (National Archives, Photographic Division, Box 2033, Number 30847)

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"In effect, the XF-92 is a nonexpendable, inhabited missile with a pilot guiding the plane to its target. Since the aircraft is inhabited, it can return to its base to be used again."
Historian Ardath H. Morrow, describing the Convair XF-92 rocket powered interceptor.[1]

Chapter 11
Buck Rogers Meets Rube Goldberg: Experimental Jet Prototypes

During the second half of the 1940s, the Air Force commissioned a considerable number of jet and rocket prototype aircraft. Some of these were intended to be unique test aircraft, built to accomplish specific purposes. Such test aircraft included the rocket-powered Bell X-1 and X-2, designed to achieve ever-higher speeds, the Douglas X-3 Stilleto, intended to test the effects of air friction on the airframe of a high-speed aircraft, and the Bell X-5, a direct copy of the German Messerchmitt P.1101, which served as a test bed for the concept of variable sweep wings, that is, wings where the angle of sweep could be adjusted to different degrees to determine which angles worked best for certain flight conditions. These special aircraft all served important functions in advancing the frontiers of knowledge of high-speed flight, yet as they were never intended to be more than experimental projects, they will not be further considered in this work.

There were, however, a number of fascinating prototype jet aircraft designed and built during the later 1940s that were intended to become combat aircraft. These prototypes were built and tested, yet only one of them ever achieved production status, and that only in a significantly modified form. The others were all relegated to obscurity by advancing technology and the changing needs of the Air Force. But any account of Air Force jet aircraft of the 1940s must include a consideration of these aircraft and the purposes they were intended to fulfill.

There were six of these unsuccessful pre-production prototypes, in three categories. Each

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of these categories will be considered in turn. The first category, that of the internally stowed, or parasite fighter, had only one candidate, the McDonnell XF-85 Goblin. The second category, high-speed interceptor, saw two competitors, both rocket powered. These were the Republic XF-91 Thunderceptor and Convair's XF-92 delta-winged airplane. The final category, penetration fighter, had three entries. These were McDonnell's XF-88 Voodoo, Lockheed's XF-90, and North American's XF-93. The XF-88 was an entirely new design, while the XF-90 had grown out of the various modifications and upgrades that were originally intended for the P-80Z, and the XF-93 was a heavily modified version of the earlier F-86, originally designated the F-86C.

The XF-85 Goblin was an attempt to solve a problem that has vexed air forces since the beginning of aerial combat. Even as early as World War I, large purpose-built bombers were being used to deliver high explosives to enemy territory. These machines, built large to carry a significant number of bombs, also carried large quantities of fuel, which gave them ranges far greater than the much smaller pursuit, or fighter planes. However, the size and weight of the bombers also slowed them down and made them large and vulnerable targets for enemy fighters. Although bombers frequently carried numerous defensive weapons, far more so than an individual fighter, the fighter's greater speed and agility let them chose the time and direction of their attacks, and it proved impossible for the bombers to adequately defend themselves against determined enemy fighter opposition during daylight hours.

There have been occasional periods in the history of military aviation where the performance of the most modern bombers was actually superior to that of any contemporary fighters. One such period was the mid-1930s, when new construction techniques and streamlining, as well as more powerful engines, were all coming into use. A similar interval

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occurred at the end of the 1940s and early 1950s, as the latest jet bombers were being built. Neither of these periods lasted for very long, and both, but especially the first one gave unfortunate credence to a theory popularized by such advocates as Guilo Douhet, Hugh Trenchard, and Billy Mitchell that "the bomber will always get through." During the 1930s the United States Army Air Force, in particular, became a powerful advocate of the bomber over the fighter. This notion of the superiority of the bomber would lead to near-disaster in the skies over Europe only a few years later.

The only real defense bombers had against enemy fighters proved to be friendly fighters. Occasional attempts to provide bombers with extra firepower to enable them to protect themselves proved to be completely ineffective.[2] If fighters accompanied the bombers, however, the friendly fighters could distract, destroy or drive off enemy fighters attempting to intercept the bombers. This was a lesson that various air forces had to relearn from time to time, often quite painfully. The best know example of this was the United States Army Air Forces' attempt to conduct daylight precision bombing over occupied Europe beyond the range of fighter escort, counting on the defensive strength and firepower of its bombers. Although American bombers did prove to be tough, durable aircraft, that was not enough to prevent them from being lost and damaged in large numbers when they were subjected to large-scale attacks by Luftwaffe fighters.

The biggest limitation on providing fighter escort was range. Within the aviation industry it was generally not considered possible for a fighter with top performance to also have the extended range to accompany bombers. Building larger, multi-engined fighters to accompany the bombers, such as Germany's Bf 110 *Zerstorer*, had proved a costly failure, as the "heavy" fighters were themselves vulnerable to smaller enemy fighters. The Japanese Navy had made considerable

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progress in increasing the range of their agile single-engined Mitsubishi Zero fighters, but only by utilizing extremely lightweight construction and eliminating protection for the pilot and fuel, which made them extremely vulnerable to opposing fighters.

Fortuitous coincidence, more than any planning by the Air Force, saved the American daylight bombing offensive. The mating of the British Rolls Royce Merlin engine and the North American P-51 Mustang airframe proved to be a war winner. The resulting airplane was one of the best fighter airplanes of the entire war, and yet had the range and endurance to accompany the heavy bombers to any target in Europe. By the end of the war, the Air Force was firmly convinced of the need to escort bombers when they were sent to attack enemy targets.

The problem of providing a bomber escort facing the Air Force in the late 1940s was two-fold. The first difficulty was that the range of the bombers was increasing rapidly. With the possibility of conflict with the Soviet Union beginning to be acknowledged, the need for a true intercontinental bomber became urgent. Earlier intercontinental bomber designs, Northrop's XB-35 flying wing, and Convair's XB-36 Peacemaker, conceived to attack a Nazi-occupied Europe from bases in North America, were pulled out, revised, built and tested. Both of these planes had a combat radius of 10,000 miles with a full bomb load. This was a more than three-fold increase over the longest-ranged bomber of World War II, the B-29.

The second element of the problem of escorting bombers was that although fighter performance was increasing dramatically with the use of jet engines, the useful range of those more potent fighters was actually decreasing, due to the much higher fuel consumption rates of those engines. To illustrate, the piston-engined P-51 had a range of almost 1,000 miles on internal fuel alone, while the jet-engined F-86 could only manage about 700 miles on internal fuel,

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despite carrying four times as much fuel.[3]

If bomber escorts were to be used, they would have to be jet fighters. This was required not only by the need to combat enemy jet fighters but even more basically by the need to keep up with the jet bombers they were escorting. Yet attempts to produce a long range jet fighter, such as the XP-83, had only produced a huge, ungainly aircraft of marginal performance and a range that was still woefully short of what would be needed.

So if jet fighters could not fly a traditional escort mission, perhaps they could be brought along by the bomber itself. This idea was not new, and it had been attempted before, most notably by two of the U.S. Navy's rigid airships, the *Akron* and the *Macon*, which each carried half a dozen of the Curtiss F9C Sparrowhawk fighters carried inside the gasbag. The Internally Stowed, or Parasite, fighter concept was one that the Air Force was determined to implement, in order to protect its all-important bomber fleet.

The idea of carrying a fighter inside a bomber was not even remotely practical until the development of the enormous B-36 Peacemaker. Even then, the fighter would be minuscule compared to more traditional fighter aircraft. So the Air Force asked McDonnell to design a fighter capable of being carried in one of the bomb bays of a B-36, which could be launched and then recovered by the bomber. The result was the XF-85 Goblin.

The Goblin's appearance was unique, dictated by the physical dimensions of its proposed storage space aboard the bomber. It resembled nothing so much as an egg with stubby little wings and several tail fins. Rather than a traditional single rudder, the Goblin had two, one on each side. They angled out from the upper portion of the fuselage, and then bent vertically. The wings were sharply swept and very short, and folded like a naval carrier airplane's to enable the

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aircraft to be tucked inside the bomber. Additional fins were located on the rear of the fuselage. A large "sky hook," which would enable the XF-85 to attach itself to a trapeze mechanism lowered from the bomber, was kept in a storage space in front of the cockpit during flight, then extended for link-up.

The XF-85 never flew with its intended parent aircraft, the B-36. All flight tests were conducted with a heavily modified B-29, nicknamed "Monstro" or "the Monster." The bomb bay was enlarged to allow the Goblin to be drawn partway into the bomber, to enable the bomber to take off and land. Two XF-85 prototypes were built, (serial numbers 46-523 and 46-524) and both were used in the program of test flights. Initial tests were performed between 22 July and 23 August 1948, with the XF-85 in the "captive" mode, that is, attached to the trapeze arrangement while the bomber flew. Instruments and the engine were tested while captive. No significant problems were encountered during this stage of the tests.[4]

The two XF-85s then made a series of seven test flights, with 46-524 making the first six and 46-523 making the last one. These flights all began with the XF-85 uncoupling from the B-29 and then attempting to re-engage with the trapeze. The first of these attempts nearly ended in disaster, when the surging Goblin shifted up and smashed its canopy into the bar of the trapeze, cracking it and knocking off the pilot's headgear, including the oxygen mask. Although the McDonnell's test pilot, Edwin F. Schoch, who flew all the test flights of the XF-85, was startled, he was not injured, but he decided to abort the hook-up attempt, as he could not re-attach the oxygen mask. The XF-85 had been equipped with a sprung steel skid attached to the bottom of the fuselage for just such a situation as this. An emergency landing was made on the desert floor at Muroc, with only minor damage to the airplane.[5]

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The next three flights all resulted in successful hookups, but the following three all ended with landings on the desert floor. The almost 50% hook-up rate on a per flight basis is deceptive, however. A total of fourteen attempts were made, with only three successful hook-ups, a less than 25% success rate. There were problems with the hook mechanism on the Goblin, which needed to be reinforced and shock-absorbed to take the stresses of the coupling, and a need to increase the usable area of the hook-up bar on the trapeze, but the biggest problem was the one that had derailed all previous attempts to make the parasite concept work - turbulence. Simply by the act of flight, the big bomber produced a great deal of turbulent, unstable air all around itself. The extended trapeze arrangement generated still more, and even the little Goblin produced its share. All of this meant that as the XF-85 closed in on the bomber to attempt hook-up, the air it flew through grew increasingly disturbed. Just as the need for careful and precise maneuvers was at its greatest, the turbulent air was trying to bounce the Goblin off the bottom of the bomber or into the trapeze, and also tended to push the bomber's nose upwards.[6]

It was determined that the logical approach - from directly astern of the trapeze - subjected the little fighter to far too much turbulence to even fly safely in that position, let alone produce a successful capture. Eventually Schoch and several P-80 chase planes worked out a maneuver that offered some chance of a successful hook-up. The parasite would approach from below the layer of turbulence, and then at the last moment, nose up sharply and spurt forward, hoping to engage the trapeze in one quick movement. Although occasionally successful, this maneuver was highly dangerous and demanded extremely skilled piloting of both the bomber and the fighter. It also demanded almost ideal flying conditions, which would almost certainly be absent in a combat situation.[7]

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Although very little time was spent assessing the flying capabilities of the Goblin, Schoch was highly impressed with the maneuverability of the little craft, and P-80 chase pilots could not stay with it in turns. Top speed was estimated to be 648 mph, although the maximum recorded during the tests was 362 mph. Lack of fuel storage space in the XF-85 limited its powered endurance to 30 minutes, a severe limitation for a fighter. The proposed armament of the Goblin was to have been four .50 caliber machine guns. In almost all respects, the XF-85 met or exceeded the expectations of the design concept, and despite its unusual shape, seemed to have the potential to be a highly successful fighter airplane.

A total of seven flights were made, involving both prototypes, which lasted a total of two hours and nineteen minutes. The majority of time during these flights was spent, usually unsucessfully, attempting to hook-up with the bomber. Every one of those attempts verged on disaster. It was thought that lengthening the trapeze might mitigate some of the turbulence, although the trapeze itself would still serve as a major source of disturbance. It was eventually calculated that to lengthen the trapeze enough to move it beyond the zone of disturbed air around the bomber would leave it too weak to stand the strain of making the hook-up.

The parasite fighter was a creative attempt to meet a serious need of the Air Force. It was defeated not by any defect of design, but by the physics of fluid dynamics. Still, even assuming that the hook-up process could have been rendered simple and safe enough to have put the XF-85 into production, there are serious questions about whether the little fighter would have been effective in its intended role. Although largely unknown at the time the XF-85 was being built and tested, the Soviets were building and deploying just the sort of bomber interceptor the Goblin was designed to counter - the MiG-15. The MiG-15 was fast, tough, heavily armed and had

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excellent altitude capability. As would be seen in Korea, even the best of the American jet fighters, the F-86 Sabre, was deficient in several areas compared to the MiG-15. The ability of the F-86 to dominate the skies over North Korea was due more to the skill, training, and aggression of its pilots and the lack of the same from the enemy pilots, rather than any innate superiority of one airplane over the other. And even the protection of large numbers of F-86s was not enough to protect the B-29s from the MiGs when a substantial number of MiGs were sent after them. The B-29s were eventually forced to operate during the hours of darkness to protect them from the MiGs, notwithstanding the efforts of the F-86s to protect them.

If the hottest fighter in the Air Force could not adequately protect the bombers, even using strong teamwork and carrying plenty of fuel, it is doubtful whether the tiny Goblin would have been of much help to the bombers, with its minuscule endurance and lighter armament. Further, the Goblins would have had difficulty, with their limited endurance, in operating in the standard multi-plane elements fighter doctrine called for. Operating singly would certainly have increased the vulnerability of the XF-85 and decreased its effectiveness. The performance and maneuverability of the Goblin would almost certainly not have been enough to overcome the other advantages of the MiG-15. At best, the XF-85 would probably have proved a nuisance to Soviet interceptors, rather than a deterrent.

The Air Force, recognizing the insurmountability of the hook-up problems, canceled the parasite program in the summer of 1949. The two prototypes were the only Goblins produced. Both survive today. One is part of the Air Force museum at Dayton, Ohio, while the other is part of the outdoor museum at Offutt Air Force Base in Nebraska.[8]

This would not be the end of the Air Force's attempts to bring fighters along with its large

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bombers, however. Both the F-80 and F-84 were tested in programs designed to link them up with a large bomber and be towed along while the bomber flew its mission. Moving away from the trapeze hook-up of the XF-85, these programs had some successes, but retained many problems and none were ultimately successful.

Another specialized fighter concept was the pure interceptor. Intended to provide a quick-response defense against enemy bomber attacks, the intercepter was designed to operate only in daylight hours. There was, however, no obvious need for such an airplane in the years immediately after World War II. The only nation besides the United States that possessed long range strategic bombers at the end of the war was Great Britain, and it did not seem likely that they would launch an attack on the United States. With the interceptor, the Air Force was, if anything, defending against itself.

For its intended role, the interceptor needed exceptional speed and rate of climb. The logic that drove the Air Force to produce both all-weather interceptors and high-speed daylight interceptors seems flawed, at best. It seems reasonable that the interceptor category was inspired as much by technological advances as any real need for the type. After World War II, much German research data and numerous scientists were brought to America, and given the advanced nature of much of this research, it was only natural that the Air Force might seek to make use of it.

During the war, under relentless bombardment, the Germans had developed a number of rapid response interceptors. Two that entered production were the Me 163 *Komet* and the Ba 349 *Nadder*. Both of these designs were rocket powered, capable of tremendous speed and acceleration but with extremely limited endurance. For some reason the Air Force became

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enamored of this concept late in the war, and shortly after the war ended the Air Force issued GORs intended to produce such an interceptor. The overriding requirement of these GORs was speed and acceleration - at a time when the fastest American jet fighters topped out at around 560 mph, the interceptors were expected to exceed 700 mph, and climb from a standing start to 50,000 feet in only four minutes.[9]

Given the still limited power available from any existing or planned jet engine in 1946, the interceptor GORs demanded rocket propulsion, and the two designs submitted for this category made use of rockets. Unlike German wartime designs, rockets were not to be the sole power source for these aircraft, but were to be combined with conventional jet power. The two designs for the interceptor category were the Republic XF-91 Thunderceptor and the Convair XF-92/XF-92A. Both designs were very innovative and quite unorthodox, and both were anticipated to have exceptional performance.

The XF-91 was the more conventional of the two designs, although it still utilized a number of unique features. The design owed a great deal to Republic's F-84 project, and the similarity of the fuselage of the two planes, in particular, can be seen. The XF-91 used a J47-GE-3 afterburning engine, with 5,200 pounds of static thrust available, and an unspecified additional amount using the afterburner. But this alone would not produce the speed required, and so a rocket engine was added for additional power. Initially this was to be a Curtiss-Wright XLR-27 motor with 8,430 pounds of thrust. The exhaust gases from the rocket motor were to exit the aircraft from four small tail pipes, two each above and below the main jet engine outlet. When the XLR-27 was seriously delayed and not available for the project, it was replaced with a Reaction Motors XLR11-RM9 motor, which only delivered 6,000 pounds of thrust. The tail pipes were

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modified, and the rocket exhaust vented through four pipes below the main exhaust pipe, while the upper chamber was modified to carry test instruments. Even with the less powerful rocket motor, the combine thrust of the two types of propulsion gave nearly 12,000 pounds of thrust, and promised exceptional speed.[10]

The jet/rocket combination was, in some ways, the simplest of the innovations of the XF-91. The wings were swept, as the only means to achieve the high speeds required. But in an effort to deal with the instability created by swept wings, a novel solution was adopted. In addition to leading edge slats, such as those used on the F-86, the XF-91 used inverse taper wings. This meant that the wings were both narrower and thinner near the fuselage, and wider and thicker at the tips. The thinness at the fuselage decreased drag, and the thick, wider tips increased stability and lessened the tendency of the tips to stall at low speeds. This wing design worked very well, although from certain angles it made the XF-91 look like someone had stuck the wings on backwards.[11]

Another result of the wing design was that the wings were too thin to hold the landing gear near the fuselage, so the landing gear retracted outward, towards the tips. Also, to enable the gear to fit into the wings, rather than one large wheel on the gear legs, there were two smaller ones in a tandem arrangement. One final innovation with the wings was to permit the pilot to change the incidence of the wings in flight, from -2 degrees to +6 degrees. The incidence of the wings is the angle of the wing relative to a horizontal value of 0 degrees, and by altering this angle lift can be increased or drag lessened. A similar feature would be used with great success on the Chance Vought F-8 Crusader.[12]

Development of the Thunderceptor (a distinctly unimaginative name coined by combining

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Republic's "Thunder" with the intended purpose of the aircraft) proceeded slowly. The limiting factor was, once again, the power plant, although in this case it was the rocket motor rather than the jet engine that was delayed. Two examples of the XF-91 were built. Neither ever carried any armament, nor was any planned for. When the first prototype was completed, it was tested using only its jet engine for power. Even with the just the jet engine, the Thunderceptor proved to be a fast machine. Republic claimed its new machine as the first regular aircraft to break the sound barrier in a dive - a blatant bit of untrue self promotion, as the claim was made in December 1952, and George Welch had managed to do so in an F-86 back in 1947. However, on 9 December 1952 the XF-91 became the first American-built fighter aircraft to exceed mach one in level flight, which definitely was a record. Once the rocket motor was finally added to the airframe, its performance improved radically, and it set several speed records. One of the most impressive of those records was that it became the first aircraft to exceed mach one while climbing.[13]

The primary limitation of the XF-91 was endurance, of which it had almost none. Powered flight time using the rockets was only about 20 minutes. This represented about a 100% increase over the endurance of the Me 163, but was still hardly sufficient for a combat aircraft, as the Germans had discovered during the war. By this point the Air Force had reached the same conclusion, and decided to subsume the interceptor's responsibilities into the penetration fighter class.[14] This left the interceptor prototypes to be used strictly as test vehicles. During the early stages of the flight tests, before the installation of the rocket motor, one of the two XF-91 prototypes (48-861) had been fitted with a radar nose very similar to that used on the F-86D, to transform it to all-weather capability. It was in this configuration that it made most of its test flights and set its records. The other Thunderceptor (48-860) was first given a "V" shaped

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"butterfly" tail empennage for testing, before being modified to the same all-weather capability as the other machine. Of the two aircraft, 48-860 ended up in the Air Force Museum in Dayton, Ohio, while 48-861 was destroyed during a simulated crash-and-rescue drill.[15]

The other interceptor design was the XF-92. Conceived and built by Consolidated-Vultee (later Convair), this project included the active participation of Dr. Alexander Lippisch, one of wartime Germany's pioneers in swept-wing and jet propulsion development. The XF-92 project actually existed in two distinct versions, the original XF-92 and a later, much simpler version dubbed the XF-92A. The original XF-92 concept was extremely radical, and was projected to be capable of speeds far in excess of anything else in the air.

The XF-92 (which was never named) was a combined jet/rocket/ramjet powered craft, and was referred to in official documents as a "spike diffuser" design, after its shape and function. The basic fuselage was to be a large hollow tube, with the cockpit assembly *inside* the tube at the front, protruding from the tube like the point of a spike. Rather than the traditional wing/tail structure, the XF-92 was to have three sharply swept triangular fins (an arrangement usually known as a delta wing) of approximately equal size, two acting as wings and the third as the vertical tail surface/rudder. There was only a small wheel to facilitate landings. For ground movement and take-off the craft was to be placed on a wheeled trolley, which would also contain fuel reserves to power the plane during take-off.[16]

Even more unorthodox than the exterior appearance of the XF-92 were its power plants. For take-off and climbing to altitude there were four liquid fuel rockets positioned at the rear of the tube, each generating 1,500 pounds of thrust. For normal flight, in addition to the tail rockets, there were to be fifteen small, fifty pound thrust rockets arranged in rings around the interior of

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the tube. These purpose of these rockets was not the thrust they produced, although that was considered a secondary benefit, but to act as "pilot lights" for the primary powerplant - a ramjet. Air entered the front part of the tube, and was compressed by the constricting layout of the interior mechanisms. Fuel injectors would spray atomized fuel into the interior of the tube, and the small rocket motors would ignite the mix of compressed air and fuel. The anticipated speed from this ramjet propulsion was expected to be in excess of 1,200 mph. Finally, to aid in maneuvering the craft while it landed there would be a small Westinghouse 19XB (later a 24C) jet engine. The craft was to be armed with four 20 mm cannon.[17]

Delays in the production of the rocket motors prevented the construction of a functional prototype, although numerous models of various sizes were built for testing. In fact, largely due to the novel construction, various scientific agencies such as NACA were arguably more enthusiastic about the project than was the Air Force itself. A progress report from November 1947 indicated the need for a number of changes, especially with the powerplants. It was determined that the Westinghouse 24C was insufficiently powerful to actually fly the aircraft by itself, and could not have been operated above 35,000 feet, so a replacement needed to be found. Eventually a liquid-cooled piston engine, a 120 hp Offenhauser, was substituted. The number of small 50 pound thrust rockets was to be increased to sixteen. The four 1,500 pound thrust rocket motors at the rear were to be replaced by three 4,000 pound thrust units. The number of these larger rockets was eventfully increased to four.[18]

With this revised configuration, the XF-92 was predicted to be capable of climbing from a standing start to 50,000 in four minutes, cruising at 630 mph for about 25 minutes, and having a top speed at 50,000 feet of 1,165 mph (mach 1.75). At the higher speed, endurance was reduced

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to about 5.5 minutes.[19]

After a great deal of testing of models and numerous small changes to the basic plan, it was decided that the planned XF-92 was too complex and expensive to be a practical aircraft. This was a period of ever-decreasing budgets for the military, and although the aerodynamic concepts of the XF-92 were exciting, there seemed to be little chance of the Air Force obtaining a practical combat aircraft from it. Therefore the original XF-92 project was canceled, and a much simpler design was substituted primarily to test the delta wing concept. This new project was initially referred to as Model 7002, and then given the designation XF-92A.[20]

The XF-92A was much more conventional than its predecessor. A cylindrical fuselage held a J33-A-23 jet engine, which produced 4,600 pounds of thrust, as well as a conventional cockpit and landing gear. A less powerful J33-A-21 engine was used for initial taxi tests, due to the J33-A-23 being unavailable at the time. The power output from the J33-A-23 engine could be increased to 5,400 pounds of thrust with a water/methanol injection system. Performance with this engine was 598 mph normally, and 631 mph with water/methanol injection. The major feature retained from the original XF-92 was the three delta fins for the wings and vertical tail surfaces. The wings used just a single moveable control surface, called an elevon, in place of the usual separate aileron and flap system used on most aircraft. The vertical fin used a rudder, giving all three fins a very similar appearance.[21]

The original J33-A-23 engine was relatively underpowered, and was quickly replaced with an upgraded J33-A-29 afterburning engine. This new engine developed 7,500 pounds of thrust with the afterburner. The new afterburner added a considerable length to the tail pipe, giving the plane a somewhat stretched appearance. The XF-92A was a very futuristic looking aircraft, and

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looked blazingly fast even sitting on the ground. Despite appearances and the new engine, however, the XF-92A was incapable of exceeding the sound barrier, although it came very close to it.[22]

The test flights of the XF-92A were quite successful, and provided the Air Force and Convair with much useful information about the delta wing configuration. Convair would put this information to good use during the 1950s with two new fighter designs, the F-102 Delta Dagger and the F-106 Delta Dart. Both were highly successful aircraft of the second generation of Air Force jet fighters, the supersonic "Century Series" fighters, named after their designation numbers.

The entire interceptor concept was one of the less well-thought-out of the post-war Air Force projects. The two interceptor designs were attempts to maximize speed and climb performance with then-current technology to enable rapid interception and destruction of enemy bombers. One criticism of this program, of course, is that there were no enemy bombers to intercept at that time, nor would there be any for the foreseeable future. But the Air Force lacked any real information about the air assets of its most likely opponent, the Soviet Union, and so planned around the bomber capability of their own Strategic Air Command. In military operations, underestimating an enemy's capabilities can produce catastrophe, so the Air Force cannot really be faulted for wanting to be able to intercept bombers.

However, the requirements they issued for aircraft to do so were clearly written in such a way as to mandate rocket interceptors, given the current state of jet engine technology. This approach is difficult to understand, as during World War II, German rocket interceptors had proven to have virtually no impact on the bomber offensive at all, even when they could be

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brought into action. The extremely limited endurance of such craft was their biggest weakness. Unless an air force possessed enormous numbers of them, such rocket interceptors were easy to counter simply by routing the bombers around their known bases. The interceptors lacked the endurance to chase bombers down, and depended on having them fly virtually over the base in order to generate an intercept at all.

Given that the Air Force had so successfully nullified German rocket interceptors during the war, it is mystifying as to why they would then want to turn around and build such aircraft themselves. One possible explanation for this might be the large number of German rocket scientists working in the American aerospace industry after the war, and the very high respect given to such individuals by Americans immediately after the war, when the mystique of German technological superiority was still strong. It would be only natural for such scientists to want to continue with programs similar to ones they had worked on during the war, and for American companies and the Air Force to defer to those desires.

The high-speed daylight interceptor category quickly faded from official Air Force policy. As early as 1947, Air Force officers were recommending that the interceptor category be subsumed in the penetration and all-weather categories. By the early 1950s, jet engine technology had advanced to the point that the sort of speed performance that had previously been available only to rocket powered aircraft could now be duplicated and even exceeded by conventional jet fighters, and so traditional air superiority fighters could also perform the same sort of minimum time intercepts of enemy bombers. Also, by this time the first generation of ground-based guided missiles were coming into production. The new Nike and Bomarc missiles were far faster than any manned fighter could be, and as improvements in radar and guidance systems continued to be

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made, the missiles completely took over the short-ranged interceptor role.

The final jet prototypes built in the late 1940s were those intended to compete in the penetration fighter category. Not intended to be as rigidly specialized as the previous two categories of fighter, the penetration fighter still possessed a primary mission - long range bomber escort. Of course, the definition of long range when applied to a jet fighter meant something quite different than when applied to a strategic bomber. The basic penetration fighter concept was that, in the event of a war with the Soviet Union, the bombers would attack from bases in the United States, while the escorts would be based in western Europe, and would fly into enemy territory ahead of the bombers to secure air superiority so that the bombers could complete their mission without hindrance. As a means of completing this primary mission, the penetration fighter was also to be capable of long-range tactical ground attack missions.[23]

There were a number of difficulties that faced a company attempting to design a fighter to meet the Air Force's penetration fighter GORs. The first was that the Air Force continually altered those requirements, forcing designers to factor in a lot of "wiggle room" in their designs to accommodate changes and a wide variety of performance requirements. The original GOR, formulated in October 1945, called for the following characteristics:

- A single-place cockpit with a bubble-type canopy
- A twin-engine, turbojet propulsion system
- Sweptback flying surfaces
- Either six .50 caliber machine guns or six 20 mm cannons with provision for external stores - fuel tanks, bombs, and rockets
- A 600 miles per hour maximum speed at best altitude
- A 10 minute time to climb to 35,000 feet and a 40,000 service ceiling
- A 900 mile combat radius with a full combat load and a system stressed for 7.33g

But even before the ink had dried on this list, a series of

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> performance changes were made: the combat radius with a full load was increased to 1,500 miles and then decreased to 600 miles; the service ceiling was raised to 45,000 feet; and the time to climb was lowered to 4.9 minutes, but the altitude was increased to 50,000 feet.[24]

The Air Force also increased the demand for structural strength, in order to accommodate the stresses of performing tactical ground attack missions.

If the changing and increasingly demanding Air Force performance requirements were not difficult enough, the companies involved in the competition had to work with jet engines of strictly limited power. The engines initially used by two of the prototypes, McDonnell's XF-88 and Lockheed's XF-90, generated only 3,000 pounds of thrust each. Even with two of these engines, these planes would be underpowered when compared to contemporary aircraft, given their projected weight.

Initially, there were two entries in the competition for the penetration fighter contract, McDonnell's XF-88 and Lockheed's XF-90. North American would add a late entry, modifying their new and highly successful F-86, which had already entered production. McDonnell's design would be the first one completed and flight tested. In many ways, the McDonnell design was the most promising of the three, but it still suffered from serious shortcomings.

The XF-88, dubbed the Voodoo, was a large aircraft, with the two J34-WE-13 engines buried in the lower central portion of the fuselage. The air intakes for the engines were in the wing roots, while the exhaust outlets were under the raised tail. The large fuselage was primarily a storage area for the enormous quantities of fuel the aircraft would require to have the range performance the Air Force wanted. The wings were swept at a 35 degree angle. The cockpit was pressurized and came with an ejector seat. The armament was to be six 20 mm cannon, three on

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each side of the fuselage below the cockpit. The pointed nose would house the radar for the ranging and gunsight.[25]

The initial XF-88 made its first test flight on 20 October 1948, and generally performed adequately. It was, however, underpowered, sluggish, and slow. As a result, the second prototype was given J34-WE-22 afterburning engines, which raised the power output to 3,600 pounds of thrust per engine. The upgraded prototype was given the designation XF-88A. Even this increased power could only produce about 700 mph, and the plane remained underpowered. Of the three penetration prototypes tested, the XF-88 was the best overall performer, but even it fell short of the standards the Air Force desired, and they declined to contract for any production machines.[26]

The XF-88, like the American military in general, was rescued from oblivion by the Korean War. The conflict made plain the need for a modern bomber escort fighter, and the XF-88A was revived as the best thing the Air Force had available on short notice. The XF-88A was brought out of storage in late 1952 and subjected to another round of tests. In addition, the Air Force contracted for two new prototypes, based on the XF-88 but with significantly more powerful engines. The new fighter was designated the F-101, and retained the name Voodoo. The enlarged fuselage contained a pair of J57-P-13 engines, each capable of 15,000 pounds of thrust with afterburner. Not only did the new engines each produce twice the thrust available from both the engines of the old XF-88, they had a lower fuel consumption rate, which gave the F-101 a greater range. What a difference a few years had made! Ironically, the F-101 never served as a bomber escort, instead performing in the tactical ground attack and photo reconnaissance roles.[27]

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The original XF-88 prototype was also given the afterburning engines during the Korean War, and then had a 2,650 hp Allison XT35-A-5 turboprop engine mounted in the nose, to test the feasibility of a hybrid jet/turboprop concept. So configured, it was designated as the XF-88B. Although some useful data was obtained from the tests, it was generally considered that this sort of hybrid aircraft was not practical as a combat aircraft. Eventually, both XF-88 prototypes were scrapped.[28]

The second of the penetration prototypes was Lockheed's XF-90. Attempting to find a way to give the plane the performance the Air Force's changing requirements asked for with the available engine power caused Lockheed to examine at least 65 different design concepts before settling on one. The design chosen was fairly conventional, and looked similar in many ways to the XF-88. The wings and tail surfaces were swept, and the wings had leading edge slats. The two engines were located more towards the tail of the aircraft than the XF-88, and the air intakes were on the sides of the fuselage rather than in the wing roots. The six 20 mm cannon were located in a row on the bottom of the fuselage, underneath the air intakes. Like the XF-88, the XF-90 had a pressurized cockpit with an ejection seat. Despite its large size, the XF-90 looked like a modern high-performance fighter should - sleek and menacing.[29]

The major difference between the XF-90 and its competitor was structural strength. In an effort to comply with the demand for a strong ground attack machine, Lockheed used a thicker and stronger gauge aluminum for the skin of the aircraft. They also used stronger steel fittings internally, giving the plane great strength. When completed, the XF-90 had at least a 12g stress tolerance. Unfortunately, all that strength came at the cost of a great deal of extra weight. The XF-90 weighed half again what the XF-88 did (XF-88 - Empty: 12,140 pounds, Loaded: 18,500

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pounds. XF-90 - Empty: 18,050 pounds, Loaded: 27,200 pounds).[30] Since both aircraft used the same engines, this meant that the XF-90 was even more sluggish and slow than the XF-88. Even after putting afterburners on the engines, (and changing the designation to XF-90A) the top speed of the XF-90 was less than that of the F-86, which was already in squadron service with the Air Force.[31]

Tony LaVier, Lockheed's chief test pilot, who flew many of the test flights on the XF-90, had this to say about the aircraft:

> The XF-90's general performance was very poor. It wasn't a helluva lot better with afterburner. The plane would have had a good chance for success had it had good engines, which it didn't. The aircraft was the only one in the competition that met U.S. Air Force specifications in regard to structural strength [it was stressed for 12.5g], so it was much heavier than the other contenders. The XF-90 was the third [combat-fighter type] plane in the world to dive supersonic. The plane was also strong as hell; you could not overstress it in flight.[32]

Lockheed proposed adding more powerful engines, but as this would have entailed a complete redesign of the fuselage, the Air Force declined. When the Air Force revived interest in the penetration fighters during the Korean War, it was the Voodoo that was chosen for development. The XF-90 project was canceled, and no further aircraft were built. One prototype was eventually destroyed on the ground during a nuclear test in 1952, and the other turned over to NACA for structural testing.[33]

The final penetration fighter design was a late entry into the contest. North American decided to modify their F-86 design to enable it to compete against the XF-88 and XF-90 designs. Work on the new Sabre design, originally designated the F-86C, was begun 17 December 1947. A larger and more powerful engine was to be used, the J48-P-1, capable of 6,000 pounds static

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thrust and 8,750 pounds of afterburning thrust. The J48-P-1 was a license-built copy of the Rolls Royce Tay engine, and was a centrifugal flow, one of the last of this type used on an American jet fighter. The J48-P-1 was bulkier than the earlier Sabre engine, and so the fuselage was expanded to accommodate it. This redesigned fuselage became one of the first on an American jet fighters to use the "Area Rule." Essentially, by 'pinching' the fuselage sides near the mid-point, drag could be lessened and the airflow smoothed out. This 'wasp waist' design would become a standard feature on the next generation of American jet fighters.[34]

For the penetration role, the F-86C would need more advanced electronics (the SCR-720 search radar) which would be located in the nose. This forced North American to relocate the air intake from the nose to a pair of ducts on the side of the fuselage, below the cockpit. These ducts were based on a design contributed by NACA, and were flush-mounted. That is, the surface of the ducts was level with the skin of the fuselage, greatly reducing drag. Triangular shaped wedges were instead indented in the sides of the fuselage forward of the ducts to allow airflow into the engines.[35]

The F-86C used the same wing design, including leading edge slats, as the earlier Sabres. Armament was to be six 20 mm cannon, located on the fuselage sides. The side-mounted air brakes of the F-86 were deleted and replaced with a single large air brake on the lower fuselage. To obtain the range the penetration concept called for, much of the new, larger fuselage was filled with fuel cells, giving it a maximum range of almost 2,000 miles.[36]

All theses changes greatly increased the weight of the F-86C. The weight of the F-86A was 10,093 pounds empty and 15,876 loaded. The F-86C, by contrast, weighed 14,023 pounds empty and 21,610 loaded. To accommodate this extra weight, the main landing gear legs of the

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F-86C had two tires each, one on either side of the leg. Despite the significant increase in weight, the new engine gave the F-86C a slightly greater speed than the F-86A, 622 mph at 35,000 feet for the F-86C compared to 601 mph at 35,000 feet for the F-86A.[37]

While the F-86C was under development, the Air Force was impressed enough with the basic F-86 design to order 118 examples on 9 June 1948. They decided to redesignate the plane the F-93A, as it represented a significant change from the earlier F-86, and this was the period when the Air Force was trying to fool Congress into funding "new" aircraft by redesignating modified versions of existing planes.[38]

Two prototypes of the F-93 design were built, and formally designated as YF-93As. The first one flew on 25 January 1950. Both were eventually flown, and the aircraft competed in a penetration prototype "fly off" held between 29 June and 7 July 1950 at Muroc (now formally renamed Edwards Air Force Base, after a test pilot killed while flying an XB-49 prototype). The competition pitted all three penetration fighters against one another in an attempt to choose a winner. The XF-88 Voodoo was the overall winner of the competition, while the YF-93A came in last.

This competition, however, was moot even before it began. About the time of the contest, the Air Force had officially canceled the penetration fighter project. SAC was still the dominant element of the Air Force, and since none of the penetration prototypes seemed to have anywhere near the performance needed to successfully escort the bombers, the program was terminated. General Curtis E. LeMay, commander of SAC, expressed his views of the penetration fighter when he said "fighters are fun, but bombers are important."[39] The production order for the remaining 116 F-93As was canceled, and the funds used instead to build more bombers.

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Both YF-93As continued their flight testing program, and were eventually acquired by NACA, largely because of their flush intake ducts. Later both prototypes were modified with larger, expanded ducts for additional tests. Eventually both prototypes were scrapped.

The penetration fighter program was an attempt to fill a significant need for the Air Force. Unfortunately, it was doomed from the start by a combination of the Air Force's strict and frequently changing requirements and the limitations of existing jet engine technology. The revival of "the bomber will always get through" mentality as part of SAC's command structure did not bode well for the program, either. It would take several years of bitter combat experience in Korea before the need for effective fighter escort was admitted once again, prompting yet another round of fighter development.

In the end though, fighters were never able to catch up to bombers in terms of range and endurance, which ultimately pushed bomber design into directions intended to prevent interception, by increasing speed, altitude capability, and ultimately, adding stealth capacity. This would produce such bomber designs as the B-52 Stratofortress, the XB-70 Valkyrie, the B-1 Lancer, and the B-2 Spirit. Fighter evolution ultimately pushed in the direction of air superiority and ground attack missions, and the bomber escort mission has largely faded from the Air Force repetoire.

All of the aircraft in this chapter were designed to meet specific needs of the Air Force. All of the designs demonstrated considerable creativity and a willingness to consider new ideas. All were handicapped by the relatively crude and low-powered engines that were the only ones available to designers at the time these planes were conceived. The difference between the XF-88 and F-101 versions of the Voodoo is a matter of little more than five years, yet the relative

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difference between their engine power is amazing (6,000 pounds vs. 30,000 pounds total thrust). The failure of these aircraft rests not on poor ideas or lack of persistence, but on the limits imposed by current technology. The aircraft in this chapter represent classic illustrations of trying to do too much with too little.

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1. Ardath H. Morrow ***Case History of the XF-92*** Historical Office, Executive Secretariat, Air Material Command, Wright-Patterson Air Force Base, June 1949, Introduction, p. 1.

2. An American example was the YB-40, a conversion of the B-17F Flying Fortress. A chin turret (later standardized on the B-17G) was added, as well as an additional dorsal turret and twin machine guns at the waist positions. Loaded down with extra ammunition, it could barely keep up with regular B-17s, and could barely defend itself, let alone protect other bombers. The Germans made a similar attempt, by placing a large number of machine guns and cannon on their immense Me 323 *Gigant* six engined transport. Like the YB-40, this upgunned version proved completely useless in combat.

3. Jones ***U.S. Fighters***, pp. 127-130; 225-8.

4. Ibid., pp. 222-4.

5. "Summary of Results on XF-85 Parasite Fighter Program" McDonnell Aircraft Corporation, 5 November 1948, pp. 2-3. Record Group 342, National Archives.

6. Ibid., pp. 3-8.

7. Ibid., pp. 50-6.

8. Pace ***Edwards Air Force Base***, p. 55.

9. McLaren ***Republic F-84***, p. 28.

10. Ibid., p. 29.

11. Jones ***U.S. Fighters***, p. 243.

12. McLaren ***Republic F-84***, pp. 28-9.

13. Ibid., pp. 30-1.

14. Memo for General LeMay, "Report of Fighter Requirements Committee" 25 July 1947, pp. 1-4, Entry 172, Box 38, Record Group 341, National Archives.

15. McLaren ***Republic F-84,*** pp. 30-1.

16. Morrow ***Case History of the XF-92***, pp. 25-6.

17. Ibid., pp. 26-7.

18. Ibid., pp. 27-30.

19. Ibid., pp. 34-5.

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20. Ibid., pp. 35-7.

21. Ibid., pp. 38-9.

22. Ibid., pp. 40-5.

23. Jackson ***F-86 Sabre***, p. 41.

24. Pace ***Skunk Works***, pp. 85-6.

25. Enzo Angelucci & Peter Bowers ***The American Fighter*** New York: Orion Books, 1985, p. 303.

26. Ibid., p. 304.

27. Ibid., pp. 304, 306-9.

28. Jones, ***U.S. Fighters***, p. 237.

29. Francillion ***Lockheed Aircraft***, pp. 305-6.

30. Angelucci ***The American Fighter***, pp. 278, 304.

31. Francillion ***Lockheed Aircraft***, pp. 307-8.

32. Pace ***Skunk Works***, p. 94.

33. Francillion ***Lockheed Aircraft***, p. 308.

34. Angelucci ***The American Fighter***, pp. 351-2.

35. Davis ***F-86 Sabre in Action***, p. 15.

36. Ibid.

37. Angelucci ***The American Fighter***, pp. 346, 352.

38. Jones ***U.S. Fighters***, p. 250.

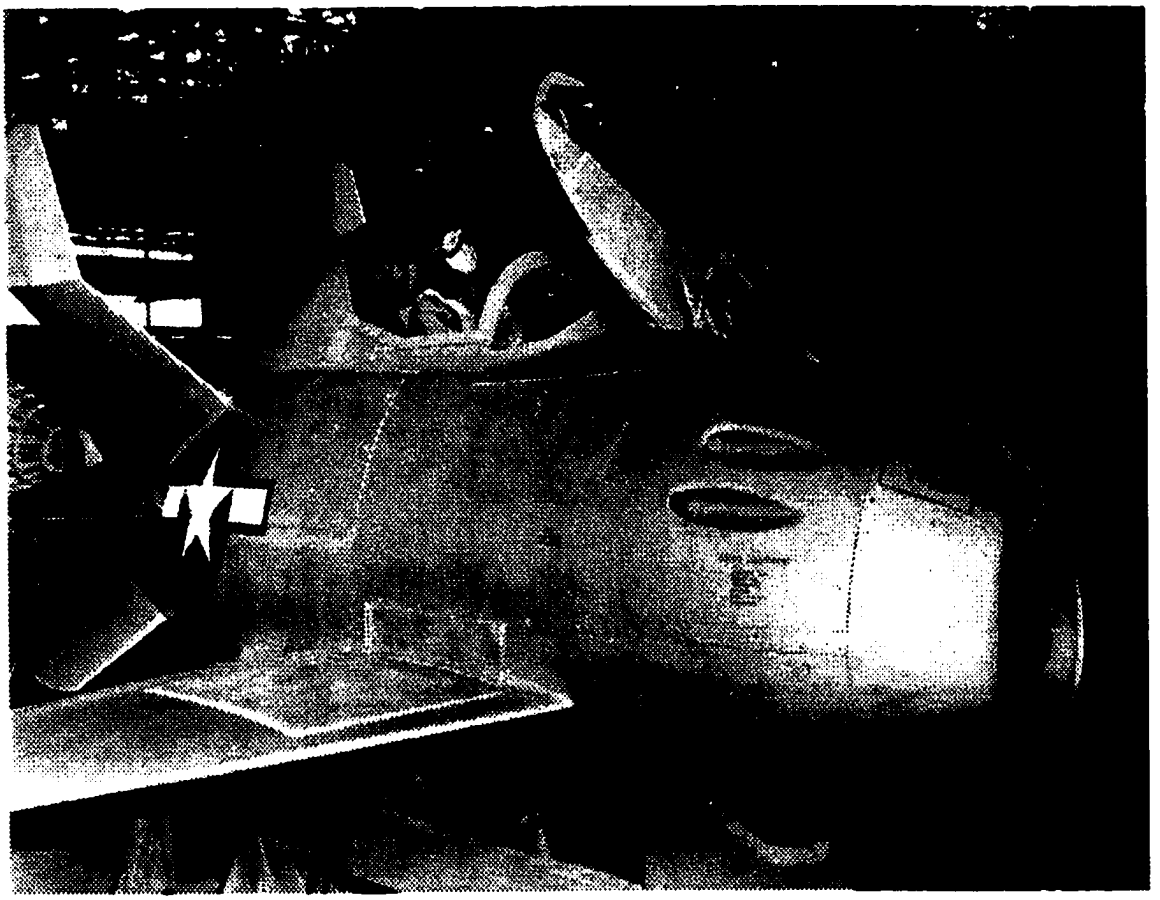
39. Dorr ***F-86 Sabre***, p. 16.

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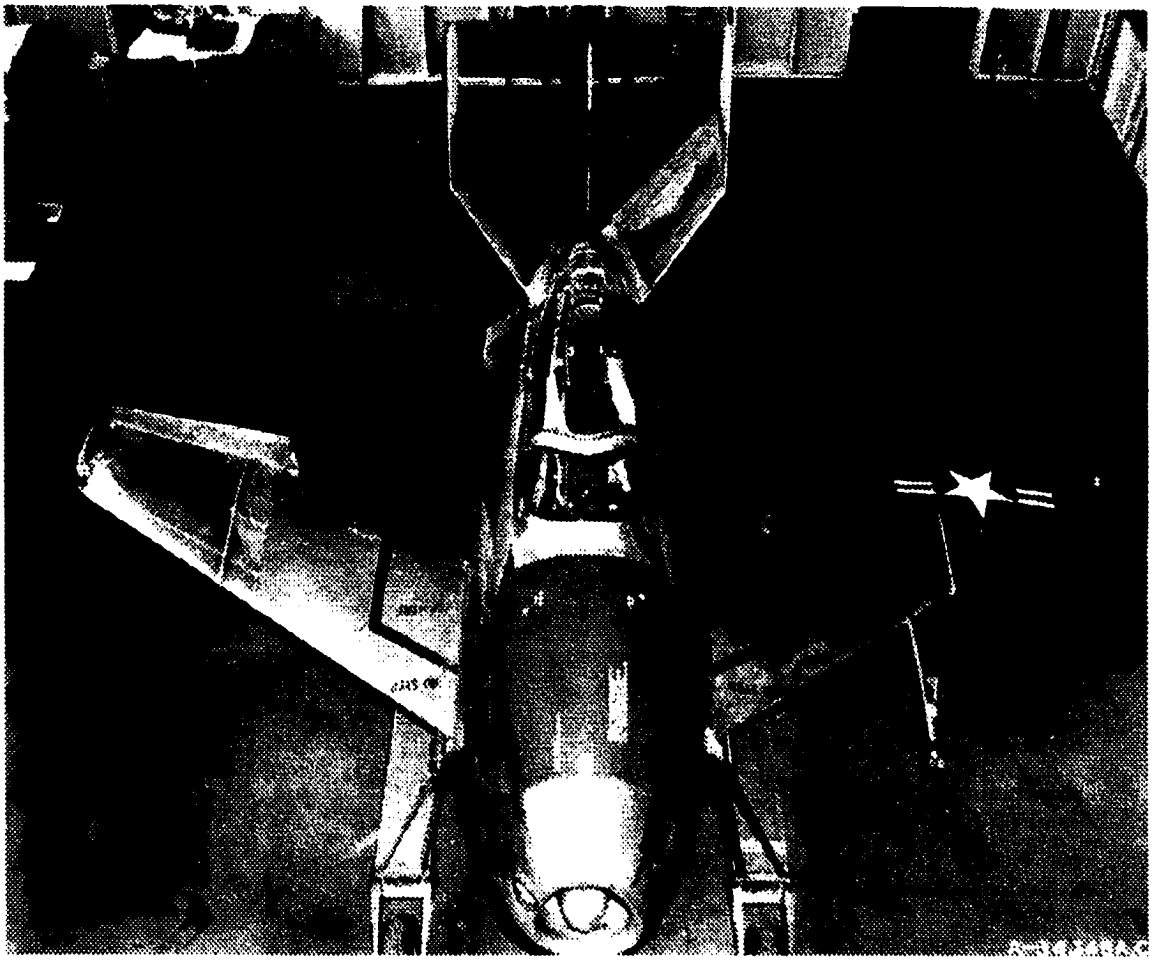
Various Air Force X planes gathered for a publicity shot. Two of these machines originated with the U.S. Navy, and two others are American-built copies of wartime German designs. The plane in the center is the Douglas X-3 Stilleto. From the lower left are the rocket-powered Bell X-1A, the jet-powered Douglas D-558-1 Navy test plane, known as the "Flying Stovepipe", the Convair XF-92A, with afterburning jet engine and painted white for visibility, the Bell X-5, a copy of the Messerchmitt P.1101 variable sweep jet fighter, the rocket-powered Douglas D-558-2, also a Navy plane, and the Northop X-4, a tailess jet-powered plane clearly inspired by the German Me 163. Photo dated 12 November 1953. (National Archives, Photographic Division, Box 2221, Number 21465)

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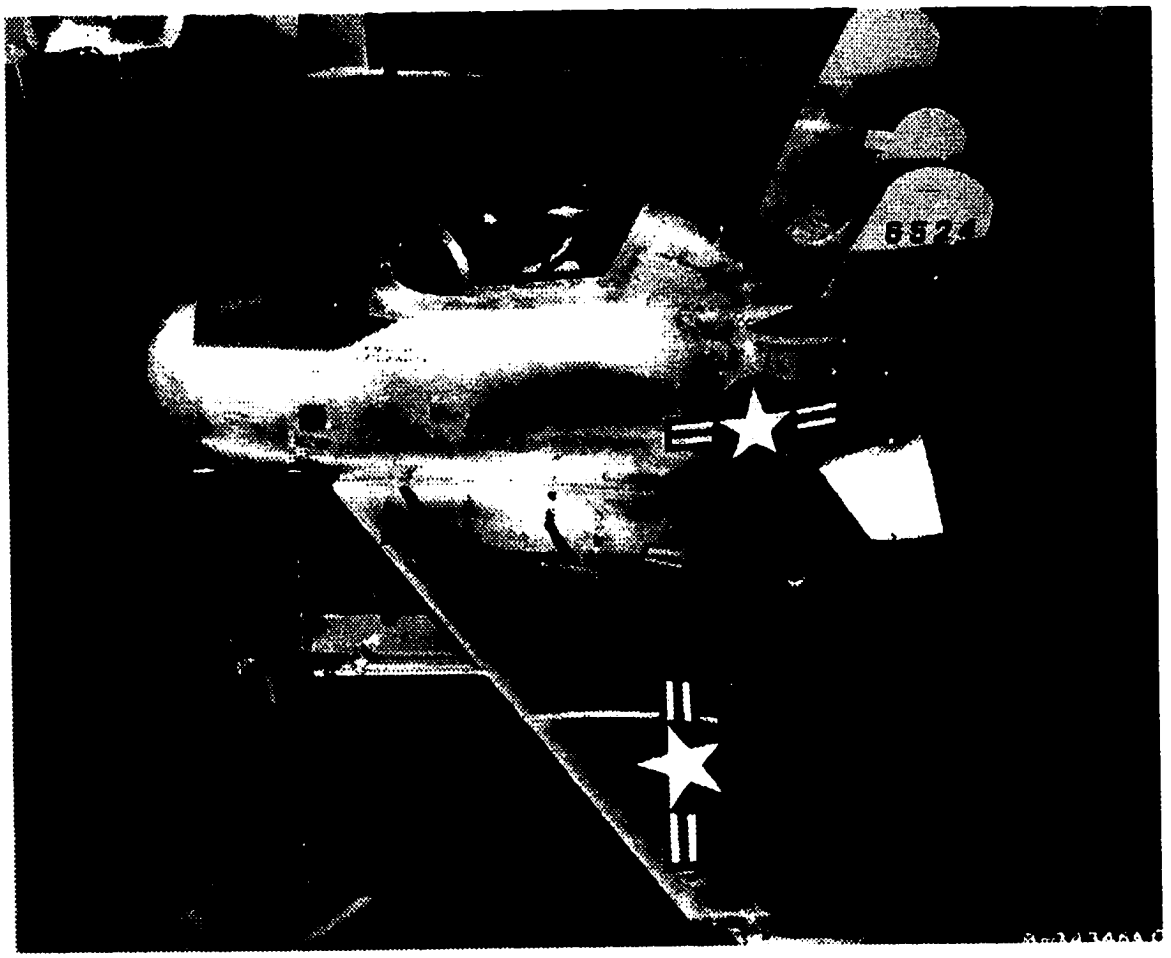
The first of the two diminutive XF-85 prototypes, seen on the floor of the McDonnell factory. The extent that the "sky hook" would block the pilot's forward vision can be imagined from this shot. The tiny size of the Goblin can be seen in comparison to the pilot seated in the cockpit, and the ports for the .50 caliber machine guns can be seen on the fuselage side. Photo credited to the McDonnell Aircraft Corporation, dated 21 July 1947. (National Archives, Photographic Division, Box 2032, Number 30475)

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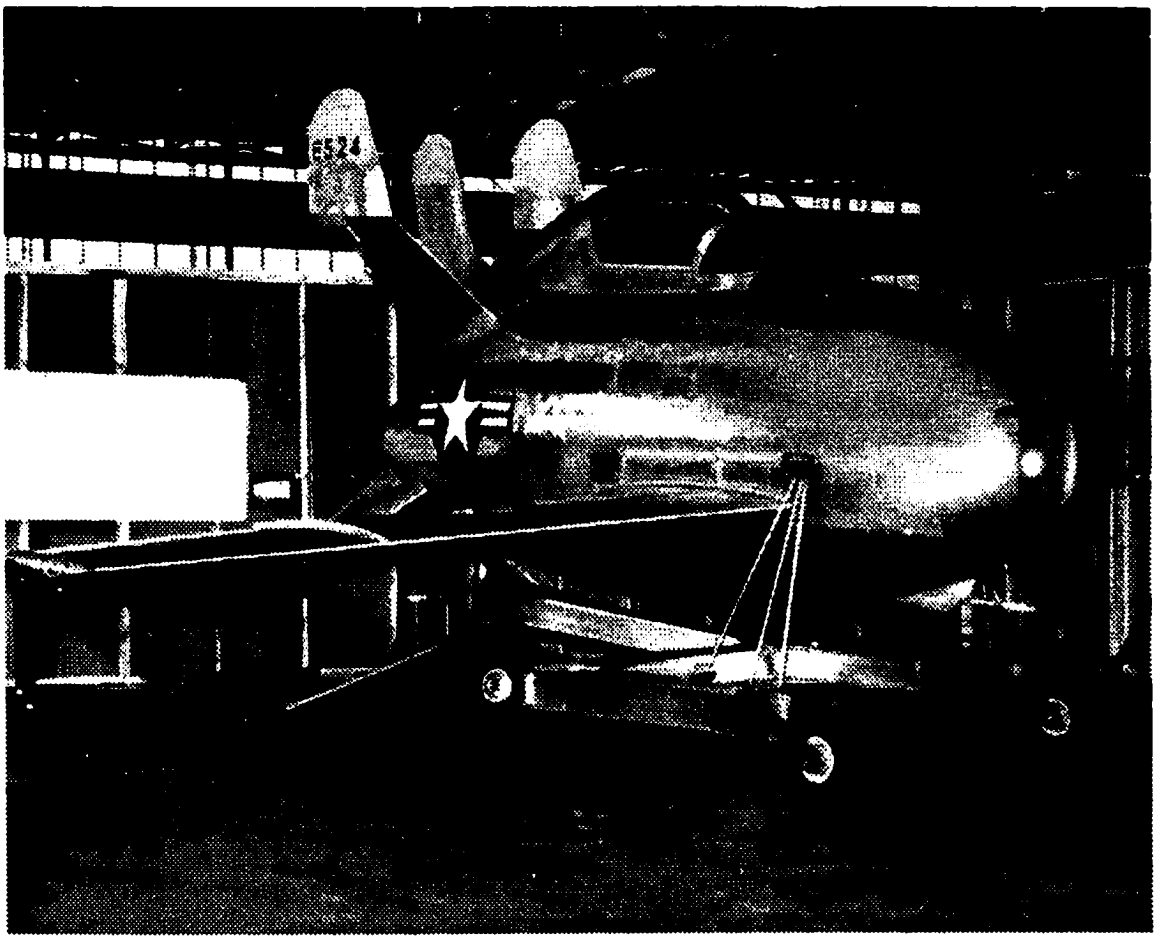
A view of the second XF-85 from above, resting on a wheeled cradle. The two angled tail fins, designed to fit inside the bombbay, can be clearly seen. The line that can be seen on both wings, running from the front to the back of the wing near the wing tip, is the joint where the wings folded up to fit inside the mother aircraft. Photo credited to Air Force Office of Public Relations, dated 13 April 1948. (National Archives, Photographic Division, Box 2032, Number 30481)

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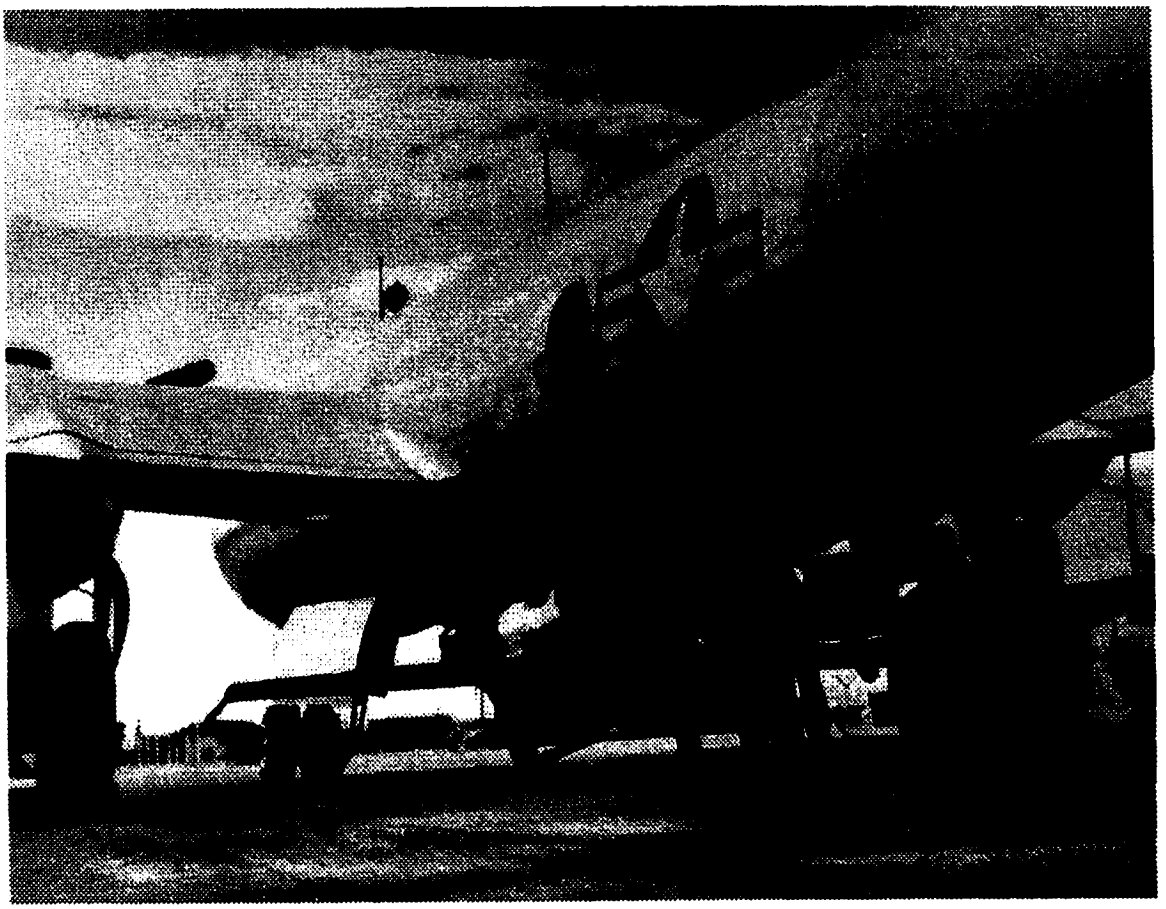
The second XF-85 prototype. Several differences between this and the first prototype can be seen in this image. The sky hook is now hidden in a compartment in the nose, rather than simply folding flat. A more visible difference is the third vertical tail fin, added between the two angled fins for additional stability. Photo credited to the Air Force Office of Public Relations, dated 13 April 1948. (National Archives, Photographic Division, Box 2032, Number 30482)

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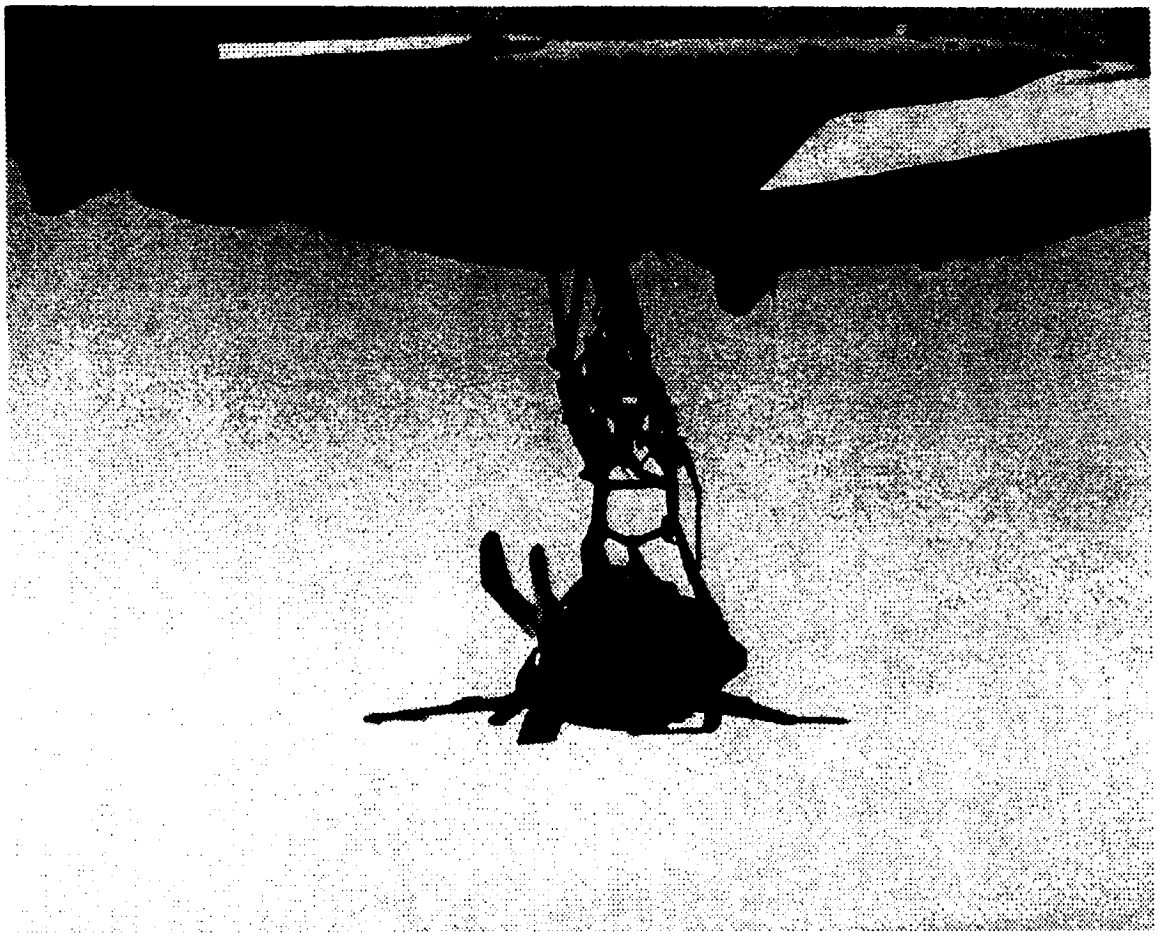
The second XF-85 prototype, on its wheeled cart. Photo credited to the Air Force Office of Public Relations, dated 13 April 1948. (National Archives, Photographic Division, Box 2032, Number 30483)

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One of the XF-85 prototypes being loaded into "Monstro" for a test flight at Muroc. Photo credited to the Air Force Office of Public Relations, dated 29 November 1948. (National Archives, Photographic Division, Box 2032, Number 30490)

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The XF-85, about to be released from its mother ship, a modified B-29 nicknamed "Monstro." The cut-away bomb bay and complex trapeze arrangement are clearly visible. On this particular flight, the hook-up attempt was unsuccessful. Photo credited to Muroc Air Force Base, dated September 1948. (National Archives, Photographic Division, Box 2032, Number 30463)

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The XF-85 at the moment of release on one of its test flights. The "sky hook" can be clearly seen in front of the cockpit of the Goblin, and the front of the sprung steel landing skid can be seen below the nose air intake, in front of the wing. Photo credited to Muroc Air Force Base, dated September 1948. (National Archives, Photographic Division, Box 2032, Number 30465)

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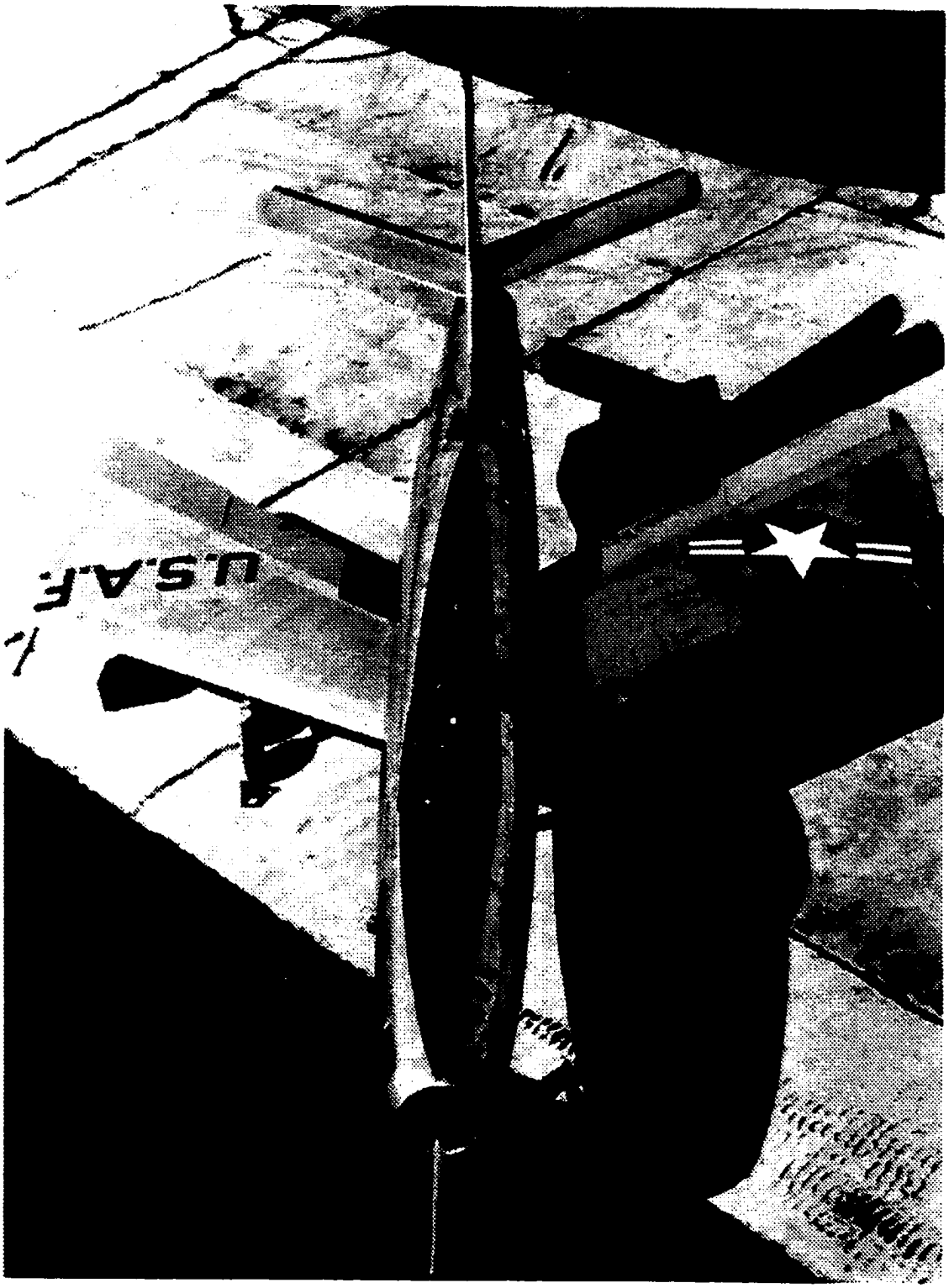
This photo perhaps best conveys the tiny size of the XF-85. Photo credited to the Air Force Office of Public Relations, dated 29 November 1948. (National Archives, Photographic Division, Box 2032, Number 30493)

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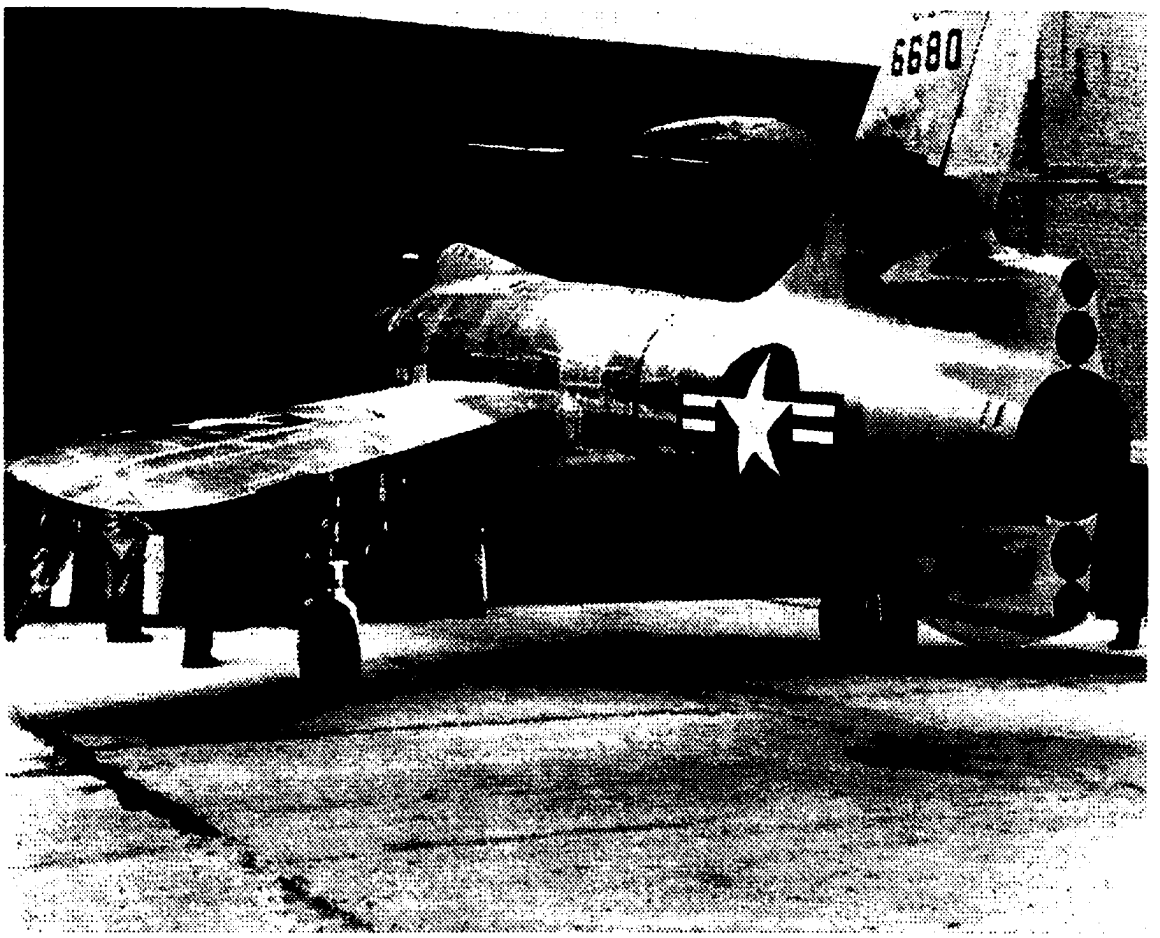
Three views of the XF-91 Thunderceptor. The tandem landing gear arrangement can be clearly seen. The large flaps hanging below the wingtips are the covers for the landing gear. Photo credited to the Office of Public Information, United States Air Force, dated 5 June 1950. (National Archives, Photographic Division, Box 2033, Number 30722)

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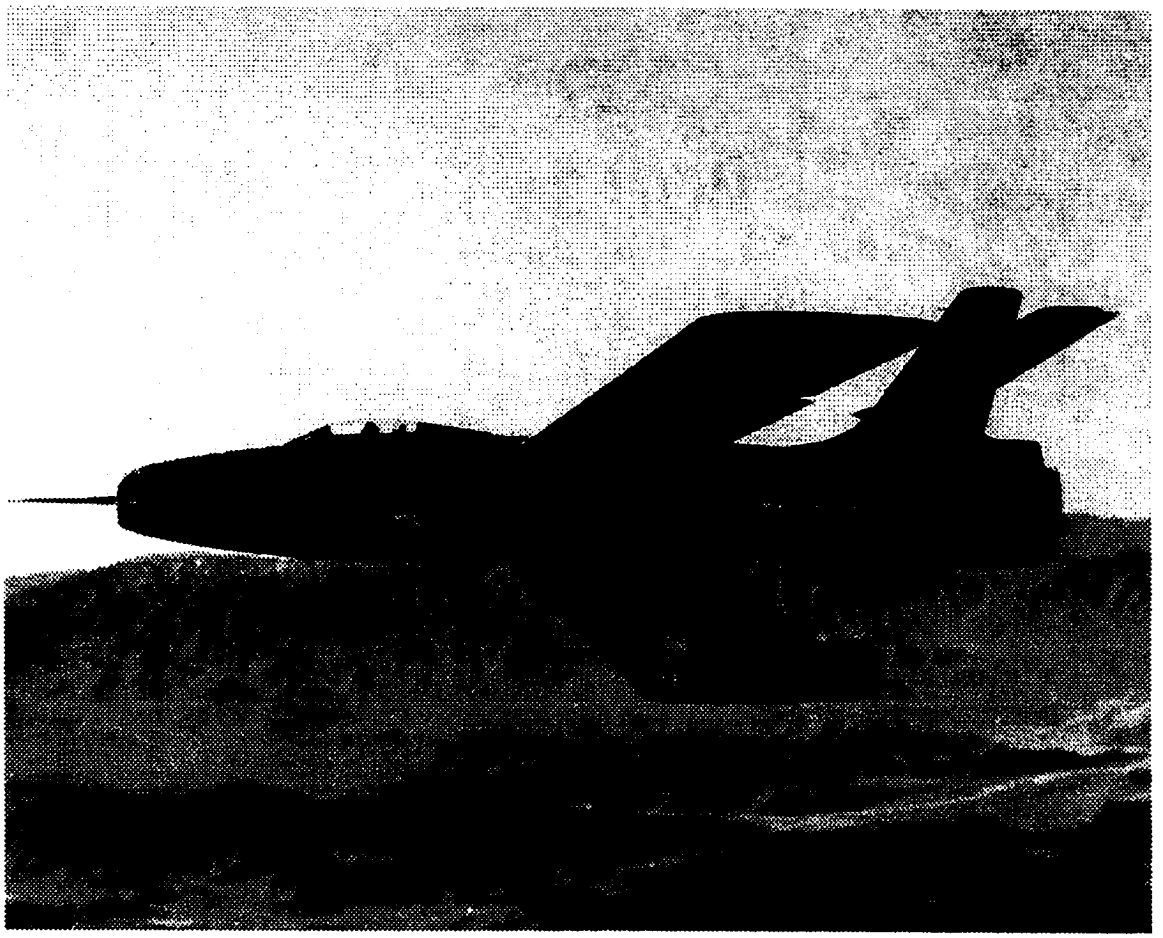
The XF-91 from the top, during taxi tests. The inverse taper wings can be clearly seen in this view. Photo credited to Republic Aviation Corporation, dated 7 March 1949. (National Archives, Photographic Division, Box 2033, Number 30729)

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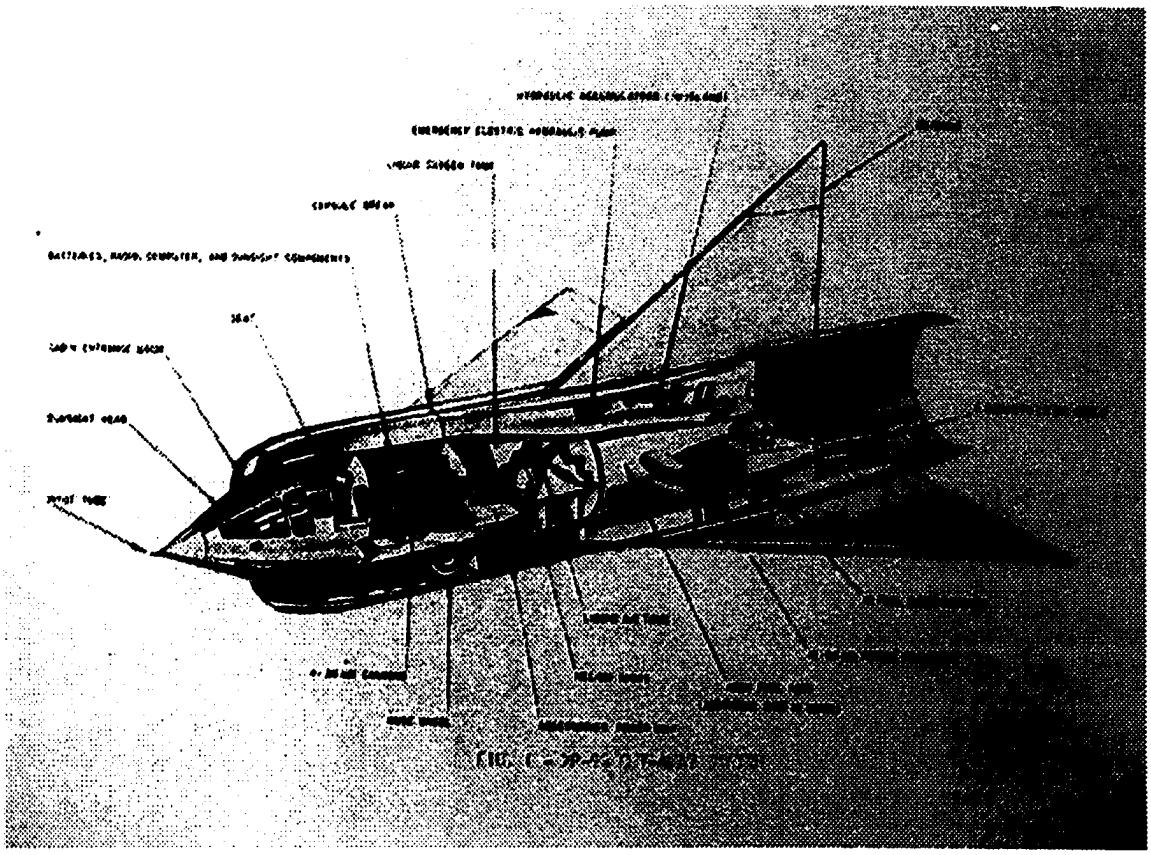
The XF-91 during taxi tests. The nozzles for the rocket exhaust can be clearly seen. The extra thickness at the wingtips can also be observed in this shot. Photo credited to the Air Force Office of Public Relations, dated 31 January 1949. (National Archives, Photographic Division, Box 2033, Number 30732)

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The XF-91 in flight. The inverse taper of the wings is again clearly visible. Photo credited to Republic Aviation Corporation, dated 10 July 1950. (National Archives, Photographic Division, Box 2033, Number 30742)

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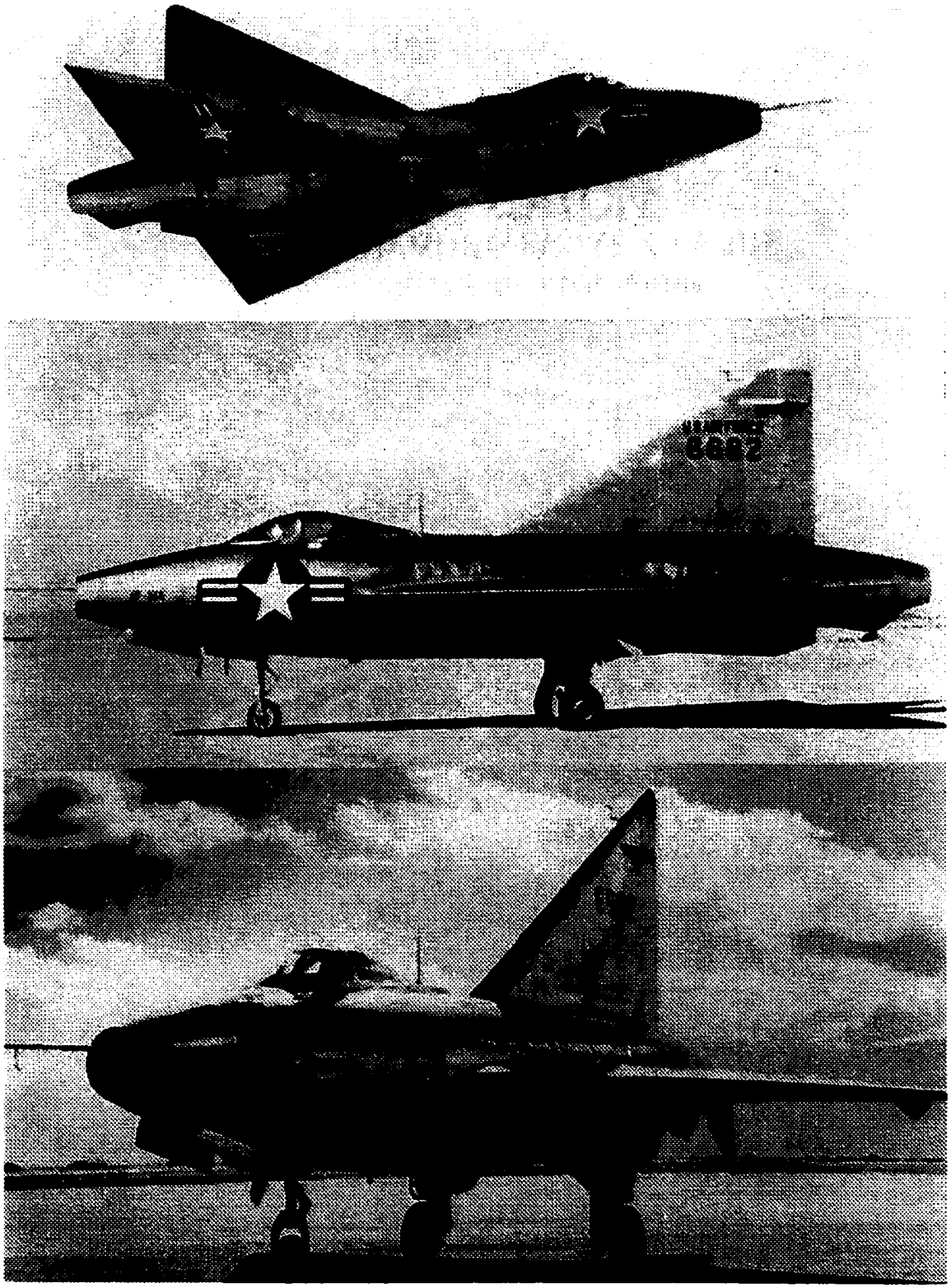
Company drawing of the proposed XF-92 spike diffuser ramjet/rocket interceptor. The location of the cockpit assembly inside the main fuselage can be clearly seen, as well as the delta wing arrangement. The small "pilot light" rockets can be seen just under the vertical fin, and the main propulsion rockets near the end of the fuselage tube. Author's photo, original drawing part of the case history of the XF-92.

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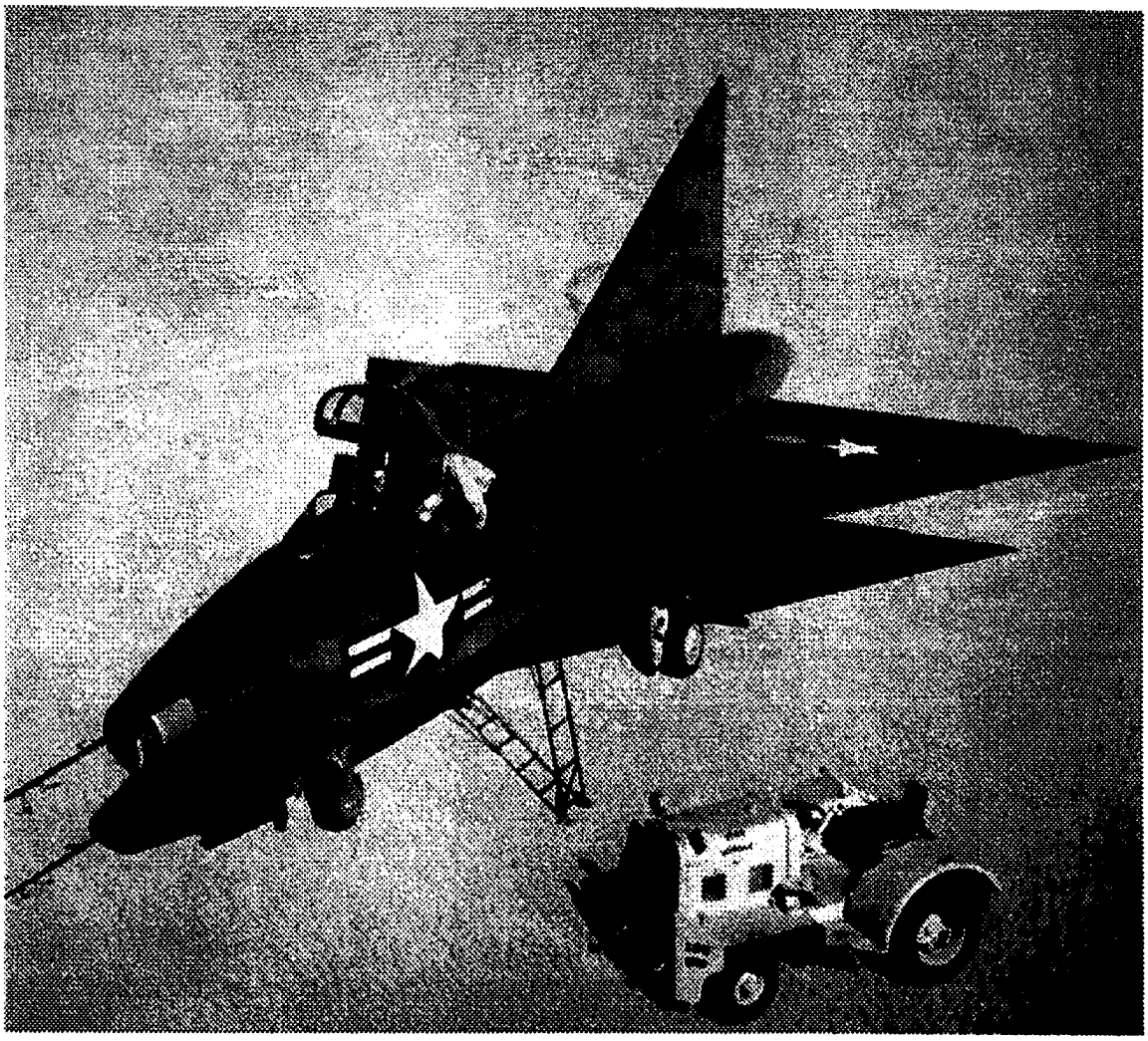
A beautiful shot of Model 7002, also known as the XF-92A, in flight. The single elevon on the wings can be seen in this shot. The futuristic, almost science fiction-like nature of the design is very noticable in this view. Photo credited to Wright-Patterson Air Force Base, dated 7 July 1950. (National Archives, Photographic Division, Box 2033, Number 30748)

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Three views of the XF-92A. Photo credited to the Air Force Office of Public Information, dated 5 June 1950. (National Archives, Photographic Division, Box 2033, Number 30749)

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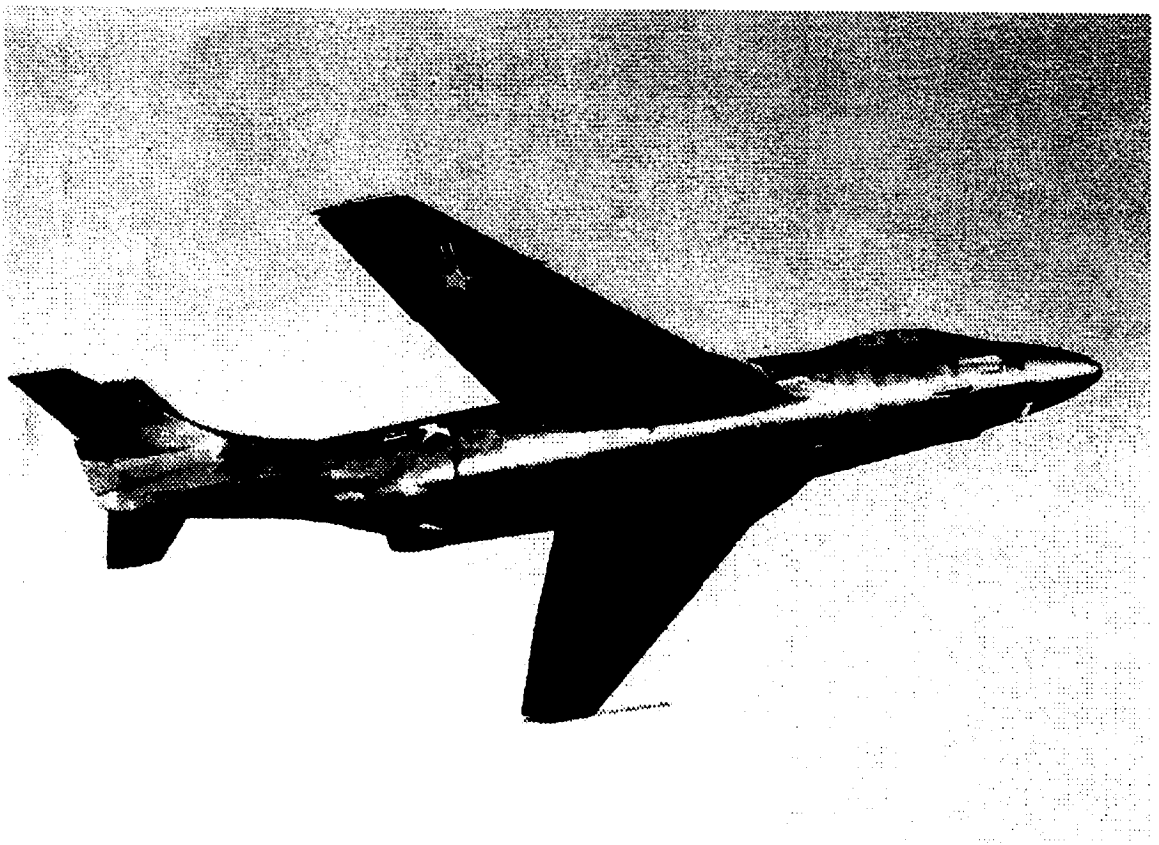
Although obviously a posed shot, this is a nice view of the XF-92A prior to a takeoff. The sharp (60 degree) angle of the wing sweep back can be appreciated in this view. Photo credited to Consolidated-Vultee, dated 23 December 1949. (National Archives, Photographic Division, Box 2033, Number 30756)

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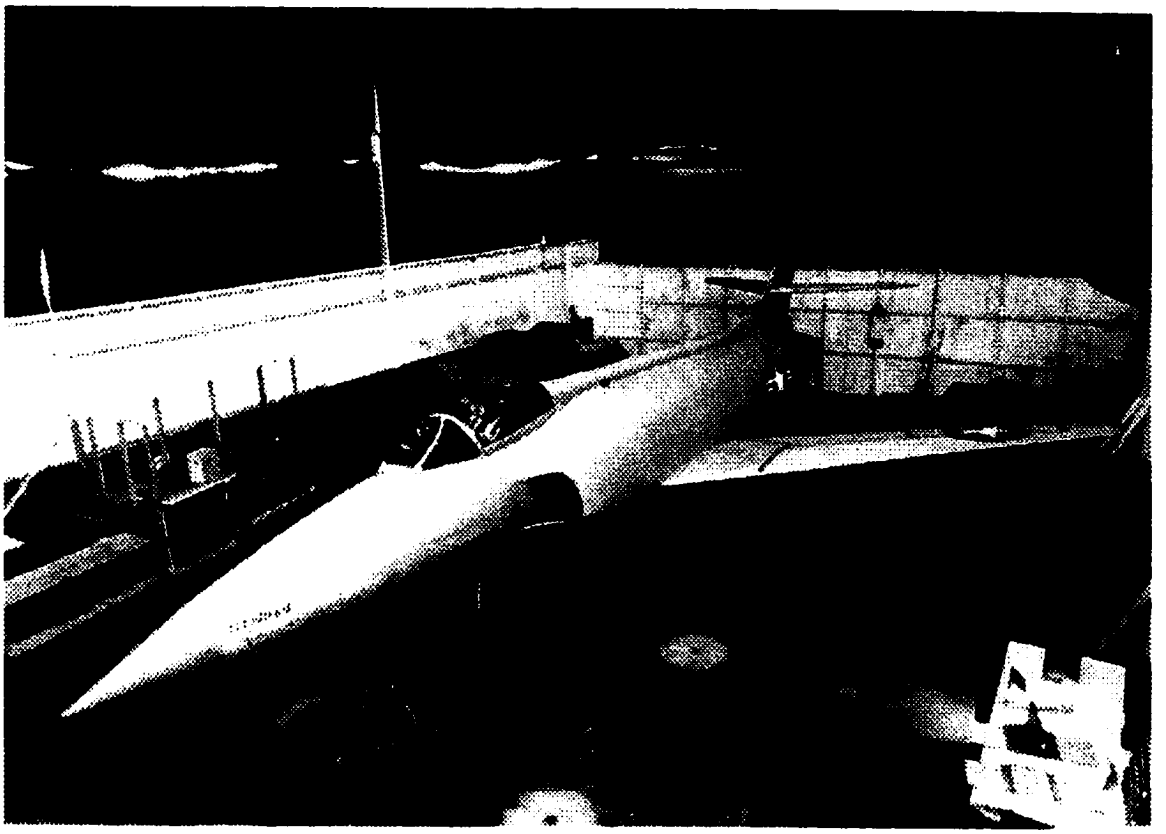
The first XF-88 prototype undergoing flight tests during the pentration fighter "fly off" competition at Wright-Patterson. The wing root air intakes can be seen in this view. The large size of the airplane, necessitated by the need to carry a great deal of fuel, can be seen in comparison to the pilot in the cockpit. Photo credited to Wright-Patterson Air Force Base, dated 28 June 1950. (National Archives, Photographic Division, Box 2032, Number 30645)

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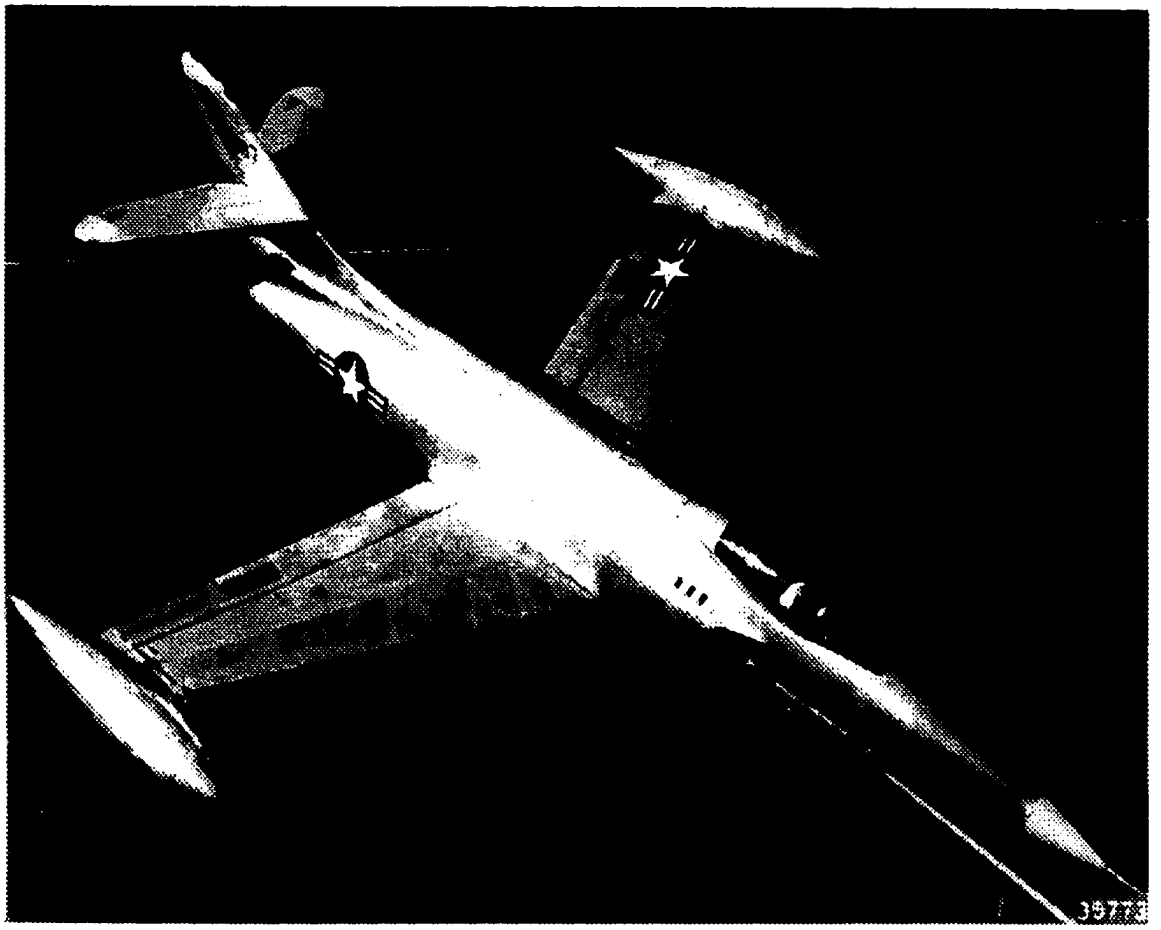
The second Voodoo prototype, the XF-88A. The nozzles of the afterburners can be seen on the rear of the engine exhaust outlets. The gunports for the proposed armament of 20 mm cannon can be seen on the side of the fuselage under the cockpit. Photo credited to Wright-Patterson Air Force Base, dated 4 December 1950. (National Archives, Photographic Division, Box 2032, Number 30646)

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The sleek and futuristic Lockheed XF-90 in a hangar at Wright-Patterson during evaluation. Interestingly, the aircraft almost appears to be painted in this photo, despite the fact that both planes were left in bare metal, and in fact were highly polished. Note that the plane does not have wingtip tanks attached. Photo credited to Wright-Patterson Air Force Base, dated 2 May 1949. (National Archives, Photographic Division, Box 2033, Number 30693)

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The XF-90 with wingtip tanks attached. Photo credited to Aircraft Branch, Research and Development, dated 31 May 1949. (National Archives, Photographic Division, Box 2033, Number 30694)

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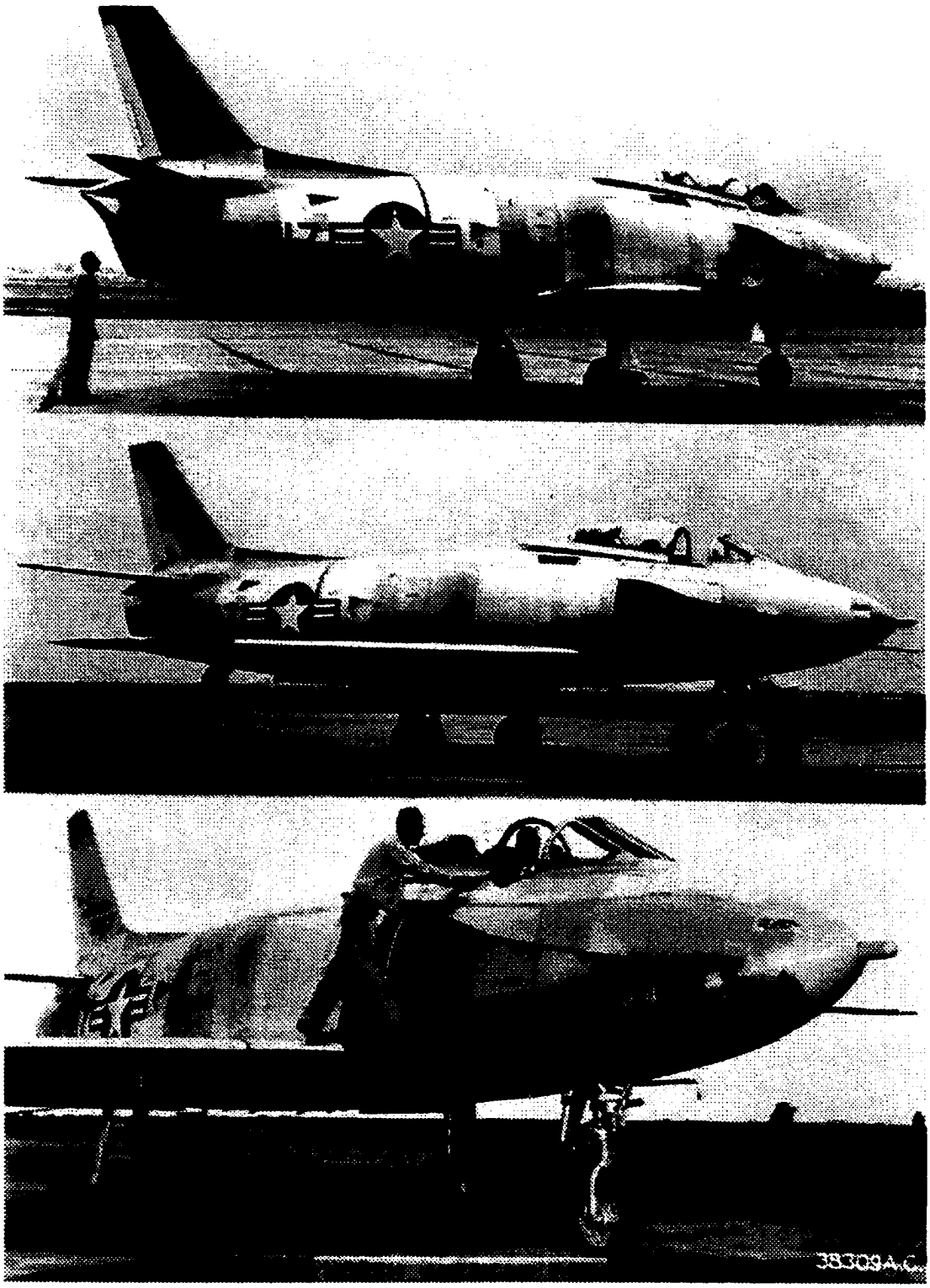
One of the XF-90 prototypes in flight from beneath, before tip tanks were added. The sealed over gunports for the 20 mm cannon can just be made out behind the air intakes, in a wedge shape, and the ejector ports for the cannon can be seen in the same pattern, just behind the leading edge of the wing. The discoloration and staining that affects even a highly maintained aircraft in flight can be seen, especially on the rear of the fuselage. Also noticable are the different shadings produced by the "grain" of the various aluminum panels. Photo credited to the Office of Public Information, United States Air Force, dated 9 August 1949. (National Archives, Photographic Division, Box 2033, Number 30697)

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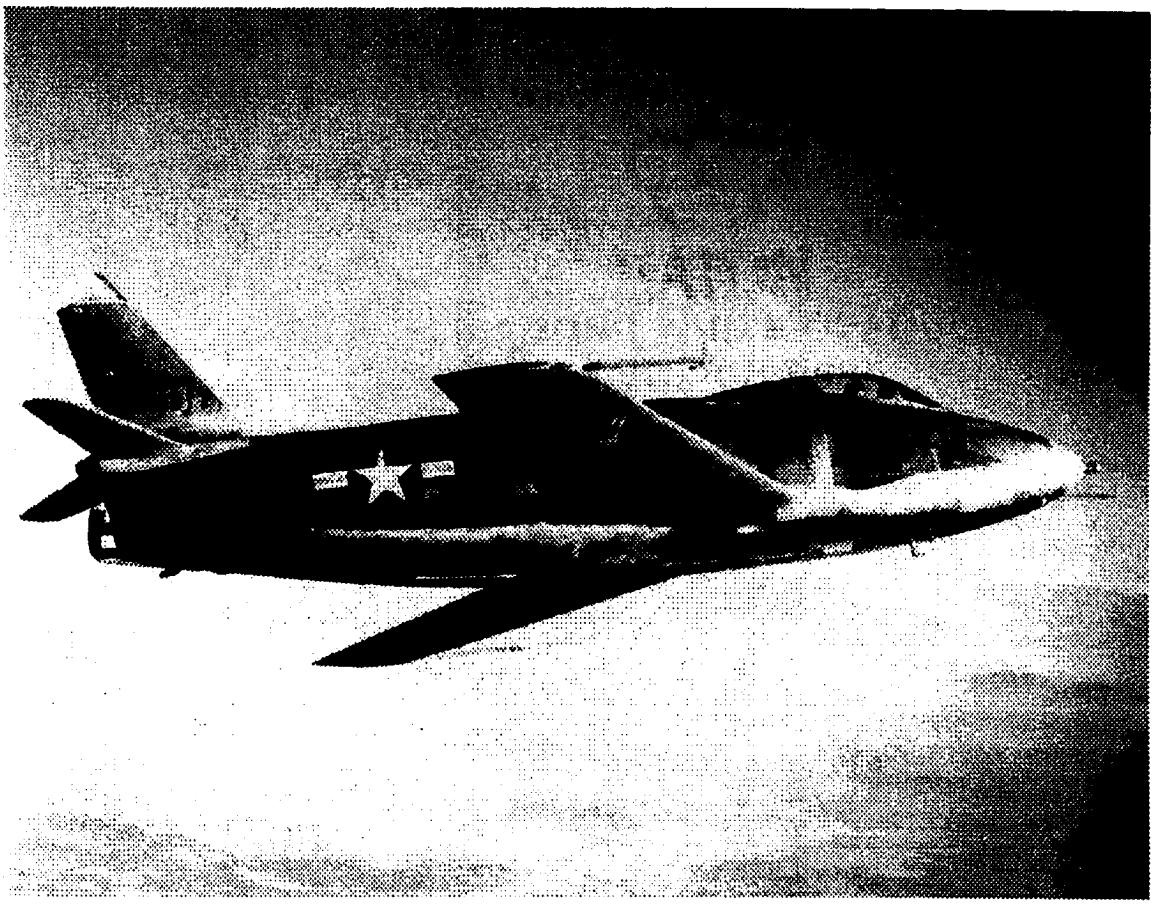
This photo captures the modern lines of the XF-90's design. The angular appearance also tends to make the plane look smaller than it is. Despite being almost the same size as the XF-88, the XF-90 does not look as big. Photo credited to the Office of Public Information, United States Air Force, dated 9 August 1949. (National Archives, Photographic Division, Box 2033, Number 30701)

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The YF-93A undergoing tests. The novel flush air intakes can be seen, as well as the double wheeled main gear. The resemblence to the orginal F-86 is apparent. Photo credited to the Air Force Office of Public Information, dated 5 June 1950. (National Archives, Photographic Division, Box 2033, Number 30767)

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The YF-93A in flight. The afterburning elements can be seen by the tail pipe. Photo credited to North American Aviation, dated 31 May 1950. (National Archives, Photographic Division, Box 2033, Number 30772)

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"Military requirements may make conflicting demands on the design characteristics. The design engineer must then balance design features and make compromises to arrive at an aircraft design that most nearly meets the military requirements."
David E. Debeau, Operations Analyst, discussing the design process for the early jet fighters.[1]

Chapter 12
Growing Pains: An Evaluation of the Development and Procurement of the Early Air Force Jet Fighters

The process by which fighter aircraft of this period were designed and built was a complex one. The earliest World War I fighters had often been designed and built in a matter of weeks, with the small construction team fashioning most of the parts (save for a handful of special ones such as the engine, weapons, and tires) themselves. As fighter aircraft grew larger, faster, and more powerful in the interwar period, their design and construction became increasingly complex, requiring specialized designers, a large and highly trained workforce, and sophisticated and expensive tools and machines for their assembly. By the beginning of World War II, the process of designing, evaluating, and producing a modern fighter aircraft could take years, cost millions of dollars, and involve not only the original company but dozens of sub-contractors as well.

In the early days of military aviation, it was common practice for aircraft companies not only to design a new aircraft, but to build several examples of it and then by demonstrations, attempt to interest the government in purchasing it for military use, even if the military had not requested any new aircraft. This practice would continue up through the early stages of World War II. Several of the war's best-known and most effective fighters were created in this fashion, including the Supermarine Spitfire, the de Haviland Mosquito, and the North American P-51 Mustang. However, as the time and expense of designing and building a fighter continued to

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grow, it became increasingly difficult for aircraft companies to undertake such a risky venture on their own resources. If the military decided not to purchase the airplane, all of the expenses incurred to produce the new model would simply be lost. The need for a financial return on their time and monetary investment in producing a new plane would eventually bring an end to this practice, and gradually push most aviation companies into closer and more dependant relationships with the government. Rather than producing aircraft largely on their own, aviation companies increasingly built new aircraft only if there was a specific government request for one.

As part of this process, the government and the military gradually assumed a greater role in the design process of new aircraft. Rather than simply expressing a need for a new aircraft, the Air Force could issue increasingly detailed 'wish lists' of performance specifications (General Operational Requirements, GORs), confident that aircraft companies would exert their utmost ingenuity in an attempt to comply with them, if they wished to get the government contracts that would allow them to survive and prosper. There was, however, a limit to the degree of control the government had over aviation companies. Since the market for combat aircraft was limited to the government, if the government became too demanding with its requirements or refused to do business with a particular company, the lack of revenue would almost certainly push that company out of business. If such closures happened often enough, soon there would be no companies left to produce the government's planes. This created a mutually inter-dependant relationship between the government and the aviation industry, and would eventually be duplicated in other industries, coming to be known as the military-industrial complex.

The process which created a new combat aircraft during the 1940s was complex. It usually began with the Air Force announcing its desire for a new aircraft and issuing a set of

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GORs. These GORs would define the type of aircraft, the mission(s) it was intended to conduct, the desired performance parameters such as speed, altitude, rate of climb, armament, range, and payload. The GORs could also include such elements as combat electronics (radar, gunsights) or any special considerations (the need to operate from small, unprepared landing strips, for example).

Aviation firms would then attempt to outline a design for an aircraft they felt could meet these specifications. These ideas would be presented to the Air Force in the form of a proposal, with drawings and details of the design. The Air Force would evaluate the various proposals received, and decide which, if any were worth further consideration. The usual practice was to select more than one design, if possible, to encourage competition and hopefully produce better results. This competitive aspect of the process was largely ignored for the first examples of the new jet fighters, due to a variety of circumstances such as the intense secrecy surrounding the projects and the desire for a completed aircraft in the minimum time possible. The companies whose proposals were selected were then asked to build prototypes of their design for evaluation.

The first stage in the prototype process was usually to create a mock-up for inspection. This was essentially a full-sized, non-functional model of the aircraft, intended to provide a sense of the size, appearance and major features of the design. If the mock-up passed Air Force inspection, construction would begin on the functional prototype. As mentioned previously, there were two forms of prototypes. The first prototypes received the designation 'X' before their letter/number designation, and were intended primarily to ascertain the general performance characteristics of the new design. X prototypes usually (but not always) lacked standard combat equipment, such as weapons, armor plate, self-sealing fuel tanks or external attachment points. If

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the testing of the X prototype(s) proved successful, then additional 'Y' prototypes were usually built. The Y machines were intended as pre-production aircraft, and almost always included the full combat equipment that had been left off of the X machines. They also included any modifications to the basic design that had been found necessary as a result of tests done with the X machines. After the Y machines were successfully tested, orders were placed for production versions of the aircraft, again incorporating any changes found necessary during the testing. Once again, the earliest jet fighters, especially those designed and built during World War II, often compressed these stages more closely. Both the P-80 and P-84, for example, received substantial production contracts well before the evaluation of even the original X prototypes was completed. The P-84, in fact, received production orders well before the X prototype was even built and flown, a fact which undoubtedly contributed to its lengthy and difficult development period.

The various prototypes and early production models were put through a series of increasingly strenuous and demanding tests. The official term for the testing regimen was Phase Testing. There were eight stages, or phases, to these tests, and the testing would continue on into the aircraft's operational career. Those phases were:

> **Phase I** Air Worthiness: flight test conducted by the contractor to demonstrate the aircraft's ability to fly safely.
>
> **Phase II** Contractor Compliance: flight tests, in which the Air Force test pilots fly the aircraft to determine if it meets the performance guidelines.
>
> **Phase III** Design Refinement: conducted by the contractor, using the same aircraft as Phases I and II, to overcome deficiencies noted during the previous tests.
>
> **Phase IV** Performance and Stability: flight test to obtain detailed data on the aircraft's performance and handling qualities.

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Phase V All Weather: tests to ascertain the aircraft's limitations under adverse weather conditions.

Phase VI Functional Development: focuses on the tactically-equipped production aircraft and identifies previously undiscovered shortcomings. Also assessed in this phase is the aircraft's durability, maintainability, logistical support, and so on.

Phase VII Operational Suitability: also known as Employment and Suitability Testing, this phase addresses the problem areas the use experiences with the acquisition of a new system (the user being the operational command such as the Air Combat Command [ACC]). The aircraft no linger being in flight test; sometimes conducted at Edwards AFB.

Phase VIII Unit Operational Employment Testing: similar to Phase VII, evaluates an aircraft at its first operational unit, using information gathered under actual field operating conditions with typical personnel and maintenance facilities. Not conducted at Edwards AFB.[2]

If an aircraft successfully passed the early Phase Tests, the Air Force would usually then issue a production contract to the company that had designed it. These contracts were usually in the form of "cost plus fixed fee," that is, the Air Force would pay a certain amount intended to cover the costs of building each airplane, plus a fee (four percent was the normal fee during this period) as a percentage of the plane's cost. However, some contracts were also done as "fixed fee," where the Air Force would simply agree to pay a flat rate for a certain number of airplanes. The Air Force tended to prefer fixed fee contracts for their simplicity and limits on spending, while the companies preferred cost plus contracts, which produced higher profits for them.

One important fact that must be kept in mind when considering the design process for aircraft during this period was that the entire process was one of considerable "trial and error." Although the principles of flight were becoming increasingly well understood, and there was an

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ever-expanding base of knowledge and data for designers to draw on, there was no way for any designer to know how a given design would perform other than to actually build and fly it. Although some information could be obtained on new models through wind-tunnel testing, not until the development of high-speed supercomputers would it become possible to accurately model the flight characteristics of a new aircraft design without building it. During earlier periods, any time a designer attempted to use new features or obtain higher levels of performance from his creation, he was entering the realm of the unknown, which could as easily lead to disaster as to success. Bill Gunston's book ***Back to the Drawing Board: Aircraft that Flew but Never Took Off*** is full of examples of failed aircraft designs. Some of these failures could barely get airborne, others failed in spectacular and deadly accidents, while still others flew well enough but failed completely in their intended purpose. Each new design was conceived and developed amid considerable uncertainty. An understanding of this fact goes a long way to explain the sometimes strenuous efforts designers went to in attempting to reuse, refine, and expand previously successful aircraft, rather than attempting to create an entirely new design.

Added to this uncertainty was the fact that the Air Force itself was by no means infallible or omniscient when it came to determining its own need for new aircraft. GORs were occasionally issued for experimental models that were never really intended to become production machines. GORs also became outdated, were revised (sometimes repeatedly), or sometimes simply canceled. During World War II, a considerable number of new aircraft were designed and built to fulfill Air Force requests, only to have the Air Force decide that they really did not need that type of airplane after all. While this decision was occasionally made after testing the prototype aircraft and deciding that it was inadequate, it was also sometimes made despite the

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excellent performance of the prototypes. As a result of these factors, the design of new aircraft was a process that carried considerable risk.

With the early jet fighters, several other elements were added to this already uncertain mix. The first of these was simply the jet engine itself. Although the jet engine promised (and eventually delivered) incredible performance and reliability, the earliest models were temperamental and trouble-prone. Jet engines also underwent extremely rapid development. Jet engines developed so rapidly during this period that it was not unknown for a new aircraft to reach the prototype stage with an engine that was already nearly obsolete in terms of power. While the piston engines used to power fighters had increased considerably in power between World War I and World War II, this was nonetheless a process that had taken several decades, and aircraft designers had time to gradually adjust to the needs and performance of more powerful engines. Also, as piston engines got more powerful, they also got considerably larger and heavier, necessitating much larger aircraft to carry them. This imposed a limit on the ability of a design team to increase the engine power of a given airframe.

Jet engines, in contrast, could increase significantly in power with only minimal increase in size and weight. This frequently allowed jet fighters to gain significantly more powerful engines with very little modification. The original XP-86 Sabre, for example, had a J35 engine with 3,750 lbs of thrust, while the F-86H, developed only a few years later, used a J73 engine that produced 8,920 lbs of thrust, more than doubling the available power to what was essentially the same airframe. This was a far greater increase in power than would have been available to a piston-engined fighter. An even more extreme example was the XF-88 Voodoo, which was originally designed with two J34 engines developing only 3,000 pounds of thrust each. So equipped, the

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plane was sluggish and underpowered. Only four years later, the design was revised to include a pair of J57 engines, producing 15,000 lbs each - taking the same basic airframe and giving it five times as much power. While the rapid development of jet engines meant that within a very short time designers were able to produce some truly remarkably performing machines, it did mean that the earliest jet fighters were often obsolete before they became fully operational. Coping with this extremely rapid technological change was another headache for aircraft designers.

Further complicating the process was the fact that jet engines allowed aircraft for the first time to produce speeds that brought them into the realm of high-speed flight and up to and beyond the sound barrier. When entering this unexplored territory aircraft designers encountered many new problems. Some of these, such as compressibility and wing separation, were very serious, while others, such as duct rumble, were simply mysterious and unnerving. But all had to be encountered, diagnosed, and overcome in order to produce airplanes capable of effectively utilizing the full power that jet engines made available. Much of what had been learned about the physics of low speed flight was useless or even dangerous when applied to extremely high speeds, and a whole new set of rules had to be learned, often through bitter experience.

Finally, the attitude of the Air Force itself in some ways contributed to the difficulties encountered in trying to design the new jet fighters. Although the Air Force's enthusiastic conversion to the idea of jet propulsion certainly provided support for the first efforts to create jet fighters, the early fighters were often hindered (or even crippled, as was the case of the P-59) by the Air Force's desire to do too much too soon with too little. By the end of World War II, the Air Force, having become convinced that jet propulsion was the wave of the future, steadfastly refused to even consider doing any more developmental work with piston-engined aircraft.

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Worse, many senior officers expected that the new jet-powered aircraft they were demanding to replace the piston-powered ones would immediately be capable of performing the same missions as their predecessors, with equal or superior performance, because, they were, after all, modern jet fighters, not obsolete piston fighters.

This attitude ran headlong into the reality that piston engines were a mature and well-developed technology, and significant performance could be extracted from them. While jet powered aircraft could certainly go faster, in many other respects the early jets were inferior in performance to their piston-powered cousins. This was particularly the case in terms of such areas as range and payload. So with the new jet fighters, while speed and altitude performance increased significantly, range and payload usually decreased by similar amounts. This did not stop the Air Force from issuing GORs for jet powered aircraft during the later 1940s that bordered on fantasy in their attempts to demand the higher speed of jets as well as the full performance range of the piston engine.

Not content merely to issue unrealistic (given the power limits of available engines) requirements for jet powered fighters, in many cases the Air Force then further increased the difficulty of the designer's job by frequently altering those requirements while the design was being developed. These changes were either prompted by news of the development of a new and still more powerful jet engine, or by the Air Force expanding the role of the proposed aircraft, or even just deciding that since it was an ultra-modern jet plane after all, it bloody well ought to be able to go even faster and carry still more weight, or perhaps travel greater distances. Frequently changing requirements in programs like the F-84 and Penetration fighter no doubt caused many aircraft designers to wish they had gone into a less stressful field, such as disarming unexploded

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bombs.

If the design process was fraught with frustration, revised parameters, and uncertainty, once a prototype was actually built, the evaluation of the aircraft was thorough and much more predictable. The orderly and well regulated phase testing was intended to be a complete evaluation of the aircraft, from the performance characteristics of the first prototype to the suitability for operational deployment of the production machines. The Air Force had had decades to create a testing system to thoroughly evaluate its new aircraft, and the process for jets did not vary significantly from that used for earlier piston-engined models.

For the most part the testing system worked well for the new jet fighters, putting them through their paces, uncovering weaknesses and offering constructive criticism. There were, however, occasions where the system did not perform as well as it might have, with unfortunate results. These deviations from the norm were usually the result of pressure applied by the high command elements of the Air Force to "speed up" the testing process. The most significant of these exceptions was the accelerated test schedule used for the P-80 during World War II. The war produced a demand for the P-80 that bordered on hysterical, and there was a great deal of pressure from the Air Force high command to get the P-80 into operation *right now*. This pressure led to significantly accelerated test schedules, and contributed to a number of fatal accidents involving the P-80, especially once it began to enter operational service.

The problems with testing the P-80 were not the fault of the testing program itself, which by and large was conducted with great emphasis on safety and thorough evaluation, but rather on the administrative decision that was made to rush early production models of the P-80 to operational units, despite the fact that the plane was by no means completely "debugged." The

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folly of this decision was demonstrated by the fact that all of the early P-80s shipped to combat units had be returned to the factory to have serious problems corrected. When the war ended and the pressure to commit the P-80 to combat faded, the testing program was allowed to return to a more measured pace, and the accident rate of the P-80 declined dramatically. So the problem with the P-80 test program was not the test program itself, but with the Air Force's deliberate decision to bypass elements of the test program and commit the plane to operational units before the the plane was completely evaluated.

The only real significant failure of the jet testing program involved the wing failures on the early F-89s. A similar problem with the F-84 had been quickly identified, diagnosed, and corrected. Had the testing system functioned with complete efficiency, the similarity in the basic design between the F-84 and F-89 would have prompted speculation about similar problems, and led to preventative measures being taken. Even without such prescience, the first, or at most second wing separation involving an F-89 should have prompted an immediate grounding of the aircraft and a thorough evaluation, based on the similarities to the incidents involving the F-84. Instead, four additional aircraft were lost in similar accidents before such a measure was taken. Once this step was taken, however, the fix proved to be relatively simple, and was quickly incorporated into the design.

The failure of the evaluation process in this case was most likely simply the bureaucratic nature of the Air Force. In the Air Force, as with any large organization, both information and decision making are heavily compartmentalized, which can hinder the exchange of knowledge or the making of quick decisions. It is entirely possible that the Air Force and Northrop personnel working with the F-89 were unaware of the wing problems with the F-84, because no one had

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decided to inform them, or that such information was restricted in some way. But overall, the testing and evaluation of the early jet fighters was performed with care and competence, allowing problems to be corrected and the aircraft to attain their full potential.

If the design process for the early jets was often one of changes and uncertainty, the actual production process was in many ways even worse. Once an aircraft entered production, the parent company was no longer the only company involved in the process. The production of an aircraft involved dozens or even hundreds of additional companies, who supplied everything from the raw materials such as aluminum and rubber, to companies that made important components for the aircraft, such as the instruments and wiring, to companies that produced entire sub-systems of the plane, such as the engine, armament, or electronics. All of these suppliers had to function effectively in order for the production schedule to be met, and a significant delay from even one of them could seriously disrupt the entire production schedule.

Further, the new jets required greater precision and higher standards of construction than earlier aircraft, due to their higher speed, which in turn required workers who were more skilled and highly trained than before. These new techniques also slowed down the construction process considerably. Building an airplane of any sort, even a relatively simple "homebuilt" kit, is a difficult and demanding process. For a powerful combat aircraft, the process is vastly more complex. Even during the peak aircraft production of World War II, the production of combat aircraft, although superficially similar to the assembly line techniques of the automotive industry, was far more complex, time-consuming, and labor intensive. For the jets, all of these factors increased significantly.

Perhaps the best way to illustrate the more complex and lengthy construction of the jets is

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by comparison. North American Aviation designed and built what were arguably the finest fighters of both World War II and the Korean War, the P-51 Mustang and the F-86 Sabre, respectively. The P-51 was in quantity production between 1942 and the first half of 1945, with serious production beginning only in 1943. During this short, roughly three year period, over 15,000 P-51s were produced. The F-86, by contrast, was in production from 1948 to 1956, more than twice as long. During this period, fewer than 7,000 Sabres were produced in America (close to 2,000 more were produced outside the country under license), despite the urgent needs of a re-arming Air Force and the combat losses incurred in Korea. During the Korean War, despite opening an additional manufacturing plant, North American found it almost impossible to keep up with production demand, due to the lengthier and more complex assembly process.[3]

In addition to taking longer to actually assemble, the new jets proved to be highly vulnerable to production delays. In fact, production delays became such a common feature of the early jet fighters that it took a truly significant delay to attract serious notice. The single largest factor in delaying production was the delivery of the engines. Much like the aircraft itself, the jet engines were large, complex, and expensive pieces of equipment, and the companies that made them were dependent on a variety of sub-contractors for timely delivery of the necessary parts. This, combined with the fact that jet engine technology was still in its infancy, and thus companies were still making mistakes in the design or construction of the early model engines, requiring frequent rebuilds or modifications, meant that the power plant availability for the early jet fighters was often sporadic at best. For radar-dependent aircraft such as the all-weather fighters, problems with the delicate and expensive radar and electronics could also be a source of significant delay.

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The early P-80 and P-84 programs had suffered some delays from problems with engine availability, but of the aircraft in this study, the one that suffered the most serious delays in production, produced by a variety of factors, was Republic's F-84F, the swept-wing version of the F-84. Work was begun on a prototype of a swept-wing version of the F-84 in 1949, and the first prototype flew in 1950. But a variety of problems combined to delay the production of the F-84F for years, with the first significant deliveries of the aircraft to the Air Force not taking place until late 1954. Even then, there were major problems with the aircraft, and it would take close to two more years before the aircraft was finally performing up to expectations and available in quantity. The Air Force was sufficiently concerned with this situation to commission a study in 1952, to investigate the causes of the delays and make recommendations. This report is worth examining in some detail, as it provides insight into some of the many different factors and delays which could affect the production of jet fighters. The following excerpts are all from this report.

> J-65 Engine - Wright Aeronautical
>
> Continual changes were made in design of certain parts, mainly to simplify production and reduce costs. However, this was not the controlling reason for failure to meet the original schedule, because the designs could have been frozen at any time when the subcontractor's plants were equipped for production. In other words, lack of machine tools has delayed production, and the time has been utilized for design refinements. In fact, it is a reasonable conclusion that if the machine tools could have been received at the originally stipulated delivery dates in April-July 1951, the first 700 JY engines might have been delivered at a rate close to original schedule.
>
> The basic fallacy was that the machine-tool deliveries originally specified would have been impossible if there had been no major defense production program. Since these machine-tool orders actually were placed six to nine months subsequent to Korea (July 1950) after many thousands of defense orders for machine-tools had already overloaded the machine-tool builders, we found it impossible to understand how officials of both Wright Aeronautical

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and Government failed to realize that many of these tools would not be delivered until late 1952 or thereafter. As of December 1950, the realistic expectancy as to the delivery of over $100 million worth of machine-tools clearly precluded any possibility of meeting the original J-65 schedule.

Note: Wright Aeronautical was given a facilities contract for $104 million for machine-tools. It must be realized that this constitutes implicit Government recognition that the Wright Aero and its subcontractors need these tools, and all J-65 schedules have been and are contingent upon delivery of the machine tools. (pp. 10-1)

Summarizing the Above Factors

We are of the opinion that the delay in the initial shipments was due to an acknowledged lack of jet engine manufacturing know-how on the part of the prime contractor and all but one of the subcontractors, inadequate time for them to become acquainted with the problems involved, and lack of realization by the prime contractor as to the time required to perfect designs, practices, and standards necessary for American production of this engine. [the J65 was a license-built copy of the British Armstrong Siddeley Sapphire engine] The lack of deliveries of machine tools has been only one contributing factor to the production delay thus far, it may well become the major factor limiting the future build-up of volume production. (pp. 37-8)

Major Factors Delaying and Limiting Production

It is difficult to provide a combined list of reasons, as revealed by 18 months of hindsight, why original delivery schedules for the four end items covered by this study were not met. The airplane, the engine, and the two component items were affected in different degrees by the various factors which caused delays - for example while a few very critical machine-tool delivery problems exist in the F-84-F program, the machine-too problem is much worse in the J-65 case by reason of the vastly greater number of tools involved. Subject to the forgoing qualification, the list below is presented:

First: Lack of planning or unrealistic planning by Government representatives, primarily at the Washington level, in establishing overly optimistic delivery schedules and in promising (or at least assuming) impossibly early delivery dates on machine tools. The prime contractors share with the Government the responsibility for the overly optimistic delivery schedules, since

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these contractors agreed to such schedules in accepting their Letter Contracts.

Second: The fact that, in the case of the F-84-F airplane and the J-65 engine, the articles had not been designed, the production engineering and tooling design had not been done, and the prototypes of the production articles had not been built, at the time the production orders were placed.

Third: The overloading of the machine-tool industry by the large volume of orders placed during the six months July through December 1950, together with the fact that the machine tools required for the F-84-F, the J-65 and the S-3 were not ordered until after January 1951, precluded early delivery of the latter.

Delay on the part of Congress in appropriating funds to permit the Air Force to carry out the heavy press forging program which it had requested long before Korea. (Affects F-84-F and other new model airplanes.)

The use by NPA of "directives" to machine-tool builders, pre-empting machine tools for programs having higher urgency than the end items covered by this study.

Fourth: The operation of the S-Urgency priority system, which up to the present writing continues to take machine tools scheduled for contractors covered by this study and direct their delivery to other contractors.

Fifth: In the case of the J-65 program, the purchase of all machine tools by the prime contractor for all of the subcontractors.

Sixth: In the cases of the airplane and the engine, the inauguration and administration of an extensive subcontracting program, which paves the way for volume production later, but which takes longer to get initial production of new items unfamiliar to the subcontractor group.

Seventh: A few cases of unnecessary delay by both prime and subcontractors and Air Force and other government agencies in the handling of paper work. (pp. 48-50)

Recommendations

In the case of component items such as the S-3 and ARN-6, and in the procurement of most other Air Force items except airplanes and engines, it is first necessary that Congress be impressed of the necessity of appropriating funds sufficiently far in advance to allow the Air Force time to plan and place its procurements and to allow thereafter sufficient manufacturing lead time before deliveries are required. Due to the changing membership of Congress and its Appropriation Committees this

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> requires a continuing education job by the Department of the Air Force and the Department of Defense.
>
> Regarding procurement of airplanes and engines it is recommended that the past practice of conducting preliminary negotiations in Washington be terminated. In the case of the J-65 engine procurement, for example, such negotiations gave rise to alleged promises by both the Government and the contractor, which were later disavowed or modified by both parties.
>
> When dealing with manufacturing companies whose normal business is production of civilian goods, preliminary negations in Washington do little harm except perhaps to waste time - and it is a moot question whether time is wasted or saved in such cases. Such prospective contractors, not normally dependent on military business, are more firm in resisting pressure to undertake contracts calling for unrealistically early deliveries. However, airplane and engine manufacturers, dependent primarily on Government business year in and year out, feel less free to say "no" to overly optimistic delivery schedules requested by high Air Force authorities in Washington. Both the F-84-F and the J-65 initial delivery schedules illustrate this point. It is believed that Procurement Division personnel at AMC would be closer to the realities of industrial production problems and would be less prone to establishing initial schedules based greatly on wishful thinking.
>
> We urge that the Washington Air Force authorities abstain from discussing contemplated airplane and engine procurements with top officers of contractor companies and that instead these negotiations be carried on from the outset at Wright Field.
>
> Design Changes
>
> Design changes are automatically curtailed under full industrial mobilization in time of all-out war. Under the present mobilization program far too many engineering changes have been permitted to be consistent with orderly production planning and subsequent production. (pp. 54-5) [4]

As can be seen from these examples, a great many inter-connected elements were part of the construction process for the early jets, and the schedule was vulnerable to disruption in a wide variety of areas. Even areas that might not at first glance seem to have much influence on jet construction, such as a machine tool shortage, could have a devastating impact on delivery

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schedules.

The process of designing, building, testing, and producing the early jet fighters was essentially the same as that used for the combat piston-engined aircraft of World War II. Jets added several additional elements to an already complex operation, however. The nature of the engines themselves, especially the earliest ones, underpowered and unreliable, combined with the fact that these engines were as new to the companies that built them as they were to anyone else, added greatly to the complexity of the process. Lack of a body of knowledge about jets, which could have been used to make informed decisions, meant that some design and production decisions were made based on faulty assumptions, leading to costly and time consuming errors and modifications. Finally, the Air Force's attitude about jet power, enthusiastic support bordering on obsession, put a great deal of pressure on the early jets to achieve performance that was usually not possible given the limits of available technology.

Understandably, it was the earliest jets that suffered most from these problems. The P-59 was designed and built, despite the virtual certainty on the part of its creator, Lawrence Bell, that the plane would be underpowered and therefore lack the performance the Air Force wanted in a jet fighter. But Hap Arnold wanted a jet fighter, and he wanted one now, so it got built anyway. Fulfilling Bell's predictions, the plane was underpowered and slower than even some piston fighters, and therefore rejected by the Air Force.

Kelly Johnson's P-80, which had outstanding performance by World War II standards, was more promising but suffered initially from delays in engine delivery and an accelerated test schedule which produced a number of unnecessary accidents and deaths. None of the accidents was the result of serious design flaws with the aircraft, but they did indicate problems with the

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early manufacturing processes, especially for the engines, as well as the need for significant pilot retraining, even for the most experienced pilots, before they could safely fly the new jets. This accelerated test schedule was the direct result of the Air Force brass deciding that the P-80 was their war-winner, the weapon to beat the German jets, and it must be produced *right now*, overriding almost all other considerations.

The development of the P-84 was even more disastrously affected by this attitude. Ordered into production even before the prototype had flown, the P-84 circumvented the normal testing routine even more seriously, and paid the price with numerous changes, modifications, and even some lethal design flaws. It took years to work out the problems, many of which could have been identified and corrected earlier in the process if the Air Force had not been so anxious to push the aircraft into operational service. Making matters worse, the Air Force, not for the last time, demanded far too much performance in too many areas from a limited power source, and the early models of the aircraft suffered some serious weaknesses as a consequence of the company making compromises in the design to meet those various goals.

The P-86 avoided such problems, largely because of two fortunate circumstances. The first was the fact that this design was essentially an "in-house" project for North American, not a design to fulfill a specific proposal, which meant that there was no pressure to conform to overly-demanding GORs with the project. Aside from a desire to achieve high speed, the company was free to create what they felt was the best design. The second circumstance benefitting the P-86 was the decision to alter the wings from straight to swept configuration. This design modification delayed the project by almost two years, and allowed plenty of time to do a thorough and effective job on the design. As a result of these factors, the F-86 was the most trouble-free of the

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early jet fighters, despite a design that was, in many ways, the most advanced, complex, and different from earlier piston-engined aircraft.

The various other early jet programs - the Penetration, All-Weather, and Interceptor projects - were, in contrast to the F-86, all created in response to specific Air Force requirements, and all likewise suffered to various degrees from the Air Force desire to do too much with too little. It is significant that of the nine prototype aircraft developed for these various projects, only three entered full production, and two of those (the F-94 and F-86D) were modifications of earlier successful jet fighters. The third of these to enter production (the F-89) was never a very successful aircraft, and quite likely would have failed in its primary mission - the interception of enemy jet bombers - had it ever been faced with a need to do so.

The design, development, and procurement of the early jet fighters was the first real manifestation of the complex and interdependent new relationship between the American government and various private corporations. This almost symbiotic relationship would eventually spread between the military and numerous other companies , and would come to be known as the Military-Industrial Complex. Before World War II, with the exception of naval shipyards, the American military had minimal impact on the national economy. During the Cold War, with a large peacetime military for the first time in national history, and a wide variety of technological advances making possible increasingly sophisticated, deadly, and expensive weapons, the American military became an increasingly important customer of American business.

Despite the eventual inclusion of a wide variety of companies, the aviation industry remained the heart of the Military-Industrial Complex. For most of the other businesses involved in this process, government contracts were merely an addition (although usually a very profitable

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one) to their normal business. For those companies producing warplanes it was different, however. In the 1920s, 30s, and early 40s, many aviation companies had built a variety of aircraft, both military and civilian. By the late 1940s, as military aircraft became increasingly complex and expensive, most companies began to specialize in either military or civilian models, rarely producing both types.

For those companies that produced military aircraft, this shift left them increasingly dependant on the American government for business. In earlier periods, a company that produced a functional combat aircraft that the American government decided not to buy had a reasonable chance of selling that product abroad. While the possibility of foreign sales remained during the Cold War (at least to allied nations) it became increasingly difficult and expensive for a company to design and build a plane without government funding, almost eliminating private corporate designs. [5] At the same time, a prototype designed for official competition stood little chance of attracting foreign buyers if it was rejected by the Air Force.

This produced a near-total reliance on the government for their very existence on the part of military aviation firms, and led to some unfortunate consequences. For the government, the Air Force could and did request some bizarre and impractical aircraft (of which the nuclear-powered bomber was perhaps the strangest), confident that the companies would do their best to build these abortions because they had no choice if they wished to survive. The companies, in turn, quickly perceived the profit potential of the arrangement, and began to take increasing advantage of the cost-plus contracts that were the norm for this arrangement. Once a design had been approved and contracted for, it became normal for it to take longer and cost more than originally estimated. Although that was sometimes the result of legitimate problems or changes in

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the design, it was often the result of a deliberate underestimation by the company on the original figures. Once the government had committed to purchasing the aircraft, they could do very little about the cost. Companies also occasionally went to extreme lengths to inflate the cost of the aircraft (those infamous $50 hammers and $400 toilet seats), and the government was forced to pay these expenses, even when they realized they were being cheated, because they literally had no choice if they wanted to have the plane produced.

Another long-term and largely unanticipated effect of the increasing complexity and expense of later generations of jet combat aircraft was the gradual decrease in the number of the combat aircraft of the air force. While the latest jet combat aircraft are undoubtedly capable of far more precise and destructive attacks than their piston-engined predecessors, they are also more expensive by whole orders of magnitude, as well as taking far longer to build. This has resulted in an air force with considerably smaller numbers of more capable aircraft. While perhaps inevitable, this makes the loss of even a single aircraft in combat or just an accident far more devastating, as well as much more difficult to replace.

This gradual reduction in size of the combat element of the Air Force, combined with the increasing American reluctance to tolerate even individual casualties in the military, whether in training or combat, is a troubling development. For all of its increasing emphasis on precision munitions and stealth technology, air warfare is still at its heart essentially a battle of attrition. Since the end of the Vietnam War, America has avoided a lengthy and costly attritional aerial campaign. An important question for American military aviation has emerged: at what point does an emphasis on ever-smaller numbers of more sophisticated aircraft and the need to minimize friendly casualties make it impossible to actually fight a serious war, because such a conflict

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would require taking unacceptable losses?

It is doubtful that the early jet pioneers even considered such ideas as they struggled to master a new technology and use it to create a new generation of successful combat aircraft. In many ways, the early Air Force jet fighters were a success despite the efforts of the senior Air Force leadership to "help" them along. That so many of these planes went on to successful military careers is a tribute to the imagination, hard work, and perseverance of their designers and builders, and the strenuous efforts of those brave and dedicated men who tested, operated, and serviced them to identify and eliminate the inevitable problems. The Air Force's entry into the jet age was not without its problems and growing pains, but those difficulties only served to make the ultimate success of these aircraft all the more impressive.

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1. David E. Debeau, Operations Analyst " Study of Relationships between Military Requirements and Design Characteristics of Turbojet Fighter Aircraft" Report No. 7, Operations Analysis, Department of Technology and Research, Headquarters, United States Air Force, 27 April 1949.

2. Pace ***Edwards Air Force Base***, p. 190.

3. Angelucci ***The American Fighter***, pp. 326-48.

4. "Report on Air Force Procurement and Production Study, April 30, 1952" Microfilm Archives, Library, Office of Air Force History, Bolling Air Force Base, Washington, DC.

5. During the Cold War, the only American jet fighter that achieved commercial success without first being accepted by the U.S. Air Force was Northrop's F-5 Freedom Fighter, which had substantial foreign sales, and was eventually used in small numbers by the Air Force as well.

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"I need a little help. I'm up here alone and I've got 50 MiGs cornered!"
Radio message from an F-86 Sabre pilot during a giant "furball" over MiG Alley, 4 September 1952[1]

Chapter 13
Trial by Fire: U.S. Jets in the Korean War

By 1950, although the United States had been producing jet fighters for nearly a decade, none of these new fighters had ever been in combat. The only jet to attain full production status during World War II, the P-59 Airacomet, was judged unsuitable for combat, and the P-80 Shooting Star was not available in sufficient numbers to equip a fighter group before the end of the war. None of the other fighters were even available as flying prototypes before the war ended. Despite all the tests and flying time since the end of the war, the ultimate question remained - how would the American Air Force's jet fighters perform in battle?

The answer to that question would be found in a place no one could possibly have foreseen - Korea. No military planner in the United States envisioned fighting a war in Korea. If war came, it was expected to come in Europe, with a massive assault by the Soviet Union and its satellite nations toward the west. This was the war the American military had been preparing for during the second half of the 1940s, despite limited budgets and force cutbacks. Training, doctrine, weapons systems, and unit deployment of the American armed forces were all oriented toward a massive, all-out, and quite likely nuclear war in the relatively open terrain of western Europe. None of these preparations adequately equipped the American military for fighting a small-scale, limited, conventional conflict in the mountainous and underdeveloped Korean peninsula.

The Korean War was a frustrating experience for the United States' military. Despite the

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fact that the United Nations had officially condemned the North Korean aggression and authorized member nations to resist it, the majority of the UN forces fighting in Korea were American. Not only did American military leaders consider the fighting in Korea, especially against the Chinese, to be "The wrong war, at the wrong place, at the wrong time, with the wrong enemy,"[2] but in the minds of most American generals the fighting in Korea in no way decreased the potential for a Soviet attack in Europe. The United States (as well as China and the Soviet Union, it was later discovered) went to some lengths to keep the war in Korea a localized affair in order to avoid the possibility of it escalating into a larger conflict, perhaps even a Third World War. Consequently, the military forces in Korea were subject to a number of restrictions, which caused many soldiers to complain about having to "fight with one arm tied behind our backs."[3] This feeling of being asked to do too much with too little was further reinforced by the fact that although the war produced a huge rearmament and expansion of the American military, very little of that expanded force ended up in Korea. Most of it instead went to Europe to deter the Soviets, or was used in the United States for self-defense.

Paradoxes abounded in the Korean War. A limited war, fought ultimately for nothing more significant than the *status quo ante bellum*, it was nonetheless the fifth most costly war in American history in terms of casualties.[4] America's mechanized and motorized ground troops, trained and equipped for a mobile war in Europe, had to learn how to fight in the flooded rice fields and mountains of a country with few roads. The ground war was fought with World War II vintage weapons and tactics, but the skies above the battlefield were the setting of the first jet-versus-jet aerial combats in history, and a place where the most advanced combat aircraft in the world dueled for supremacy. While making every effort to maintain air superiority over the

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Communist forces in Korea, UN aircraft did not attack the densely packed air bases from which the Communist aircraft operated, just over the Yalu River in China. Finally, although nuclear weapons were the cornerstone of America's military might, they were never used in Korea, partly to avoid provoking the Soviets, but largely because it was decided that there were no targets that the weapons could be used on effectively.[5]

It was in this confusing and contradictory, but no less deadly, arena that American jet fighters received their baptism of fire. Of the aircraft considered in this work that were put into large-scale production, only the P-59 and F-89 did not see combat in Korea. The P-59, of course, was deemed unsuitable for combat even during World War II; only a handful were produced, and it was retired even as a trainer shortly after the war. The F-89, by contrast, suffered numerous development delays, and even though it did enter service before the war ended, the Air Force reserved the plane for defense of the continental United States, and so it was deployed only in North America. The other production machines discussed in this study, the F-80, F-84, F-86, and F-94 all saw combat in Korea. The United Stated Navy also deployed jet fighters in Korea, namely the Grumman F9F Panther, the McDonnell F2H Banshee and the Douglas F3D Skyknight.

The United States was not the only nation to deploy jet fighters in Korea. England's Gloster Meteor was used in combat as well, although by units of the Royal Australian Air Force and not Britain's Royal Air Force. Unfortunately, the Meteor, despite upgrades and modifications since World War II, proved to be vulnerable in aerial combat and unsuited for ground attack work. Perhaps the most significant of all the jet fighters deployed in the Korean War was not a western aircraft at all. The Russian-built MiG-15 was not only deployed in far greater numbers than any other combat aircraft on either side (over 1,000 MiGs were involved in active combat

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operations by 1953), but its performance and ability to influence the air war was a profound shock to both the American Air Force and aviation industry. Any analysis of American jet fighter performance in Korea must include an evaluation of the MiG-15 and the interaction between the Soviet fighter and the American planes.

Although the Korean War has often been called America's Forgotten War, a number of recent works published on the conflict have served to bring it back to the general consciousness. Through these writings the basic events and stages of the land war in Korea have become reasonably well known, but the air war remains more obscure. Before any evaluation of the combat performance of American jet fighters during the Korean War can be undertaken, the basic elements of the air war must be reviewed.[6]

When the armies of North Korea invaded South Korea, they were supported by a small (approximately 130 aircraft) but effective air force. Like the ground forces of North Korea, this air force had been created and equipped by the Soviet Union. Its combat elements consisted of late World War II vintage piston-engined aircraft, primarily Yakolev Yak-9 fighters and Ilyushin Il-10 ground attack aircraft. The Il-10 was a modified and upgraded descendant of the rugged and famous Il-2 Stormovik, the single most produced combat aircraft in history.[7] Like the Red Air Force (*Voyenno-Vozdushnyye Sily* - VVS) after which it had been patterned, the North Korean Air Force was equipped and trained to acquire local air superiority and to provide tactical support to the army of which it was a subordinate element.

Although possessing no combat experience, the North Korean Air Force was well trained, adequately equipped, and very aggressive. It was quite effective in the opening stages of the war, largely because the only aircraft possessed by South Korea were a handful of unarmed trainers.

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There were no American combat aircraft in Korea when the war began. The nearest American military aviation units were stationed in Japan. The Fifth Air Force, which controlled the air units in Japan and was a part of the Far Eastern Air Forces (FEAF) had three groups equipped with F-80Cs and two groups equipped with F-82s stationed in Japan. There were also two groups of B-26 light bombers, a squadron of photo reconnaissance RF-80Cs, and an air transport group in Japan at the time. Earlier plans to station F-84s in Japan had been delayed by the F-84's extra-long takeoff runs and the short runways at the airbases in Japan.[8]

American combat aircraft were involved in the Korean War only days after it broke out. American diplomatic dependants were evacuated from Seoul in military transport aircraft, which were given protection by the F-80s and F-82s. When North Korean aircraft attempted to attack the evacuation aircraft and airfields, they were engaged by American fighters. The first American combat victories of the war were scored by F-82s at this time, with F-80s also scoring victories shortly afterward.[9]

As the North Korean army continued to advance and the decision was made in Washington to commit American forces to combat in Korea, American fighters and bombers began to fly ground attack missions against the North Korean forces. There were also some aerial combats between American fighters and North Korean aircraft, with the American pilots scoring repeated victories for minimal losses.

Most of the missions flown by FEAF during the early days of the war were "commuter" missions, flown from bases in Japan. Although convenient for the aircrew, allowing them to return to their families after a mission, it was not a very effective means of flying combat missions, especially for the jets. Even carrying external fuel tanks, the F-80s had a very limited range and

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endurance, and this did not leave them much time for any combat operations once in Korea. It would have been much more effective to base units in Korea itself, but there were obstacles to such a plan. First, even with the introduction of American troops, the enemy continued to push south, and there were serious questions about the ability of the American and South Korean troops to hold at all. Second, there were few airfields in South Korea, and most (and the best) of those were in the north of the country, near Seoul, which had been captured by the North within the first few days of the invasion.

Even when the fighting lines stabilized at what became known as the Pusan perimeter, and a few airfields became available in the country, these fields were small, primitive dirt strips. The jets could not be based at these fields, as they required longer and harder runways from which to operate. Fifth Air Force put in an urgent request for older, piston-engined fighters to be based at these fields, and eventually received a number of F-51 Mustangs. These F-51s performed invaluable service during the defense of the Pusan perimeter, as they were able to take off, fly a short distance, attack enemy forces, and then quickly return to base. F-51s continued to serve throughout the war, first with American forces and later with South African and South Korean Air Forces. Although the F-51 was well liked by the ground troops for its long range, relatively low speed, and ability to loiter over the battlefield, their liquid-cooled engines were extremely vulnerable to even small arms fire. Loss rates among the F-51 equipped units were the highest of any aircraft type engaged in ground support.[10]

In addition to the B-26s in Japan, FEAF also acquired a number of B-29 bombers, on loan from SAC, based at former World War II bases in the Marianas to use for strategic missions. During the battle for the Pusan Perimeter, these B-29s were also used in a tactical role,

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attempting to suppress the North Korean forces with carpet bombing, as had been done occasionally during World War II. The North Korean Air Force continued operations during this period, but was generally mauled badly whenever it encountered American fighters.

Following the landings at Inchon and the breakout from the Pusan perimeter, American aircraft continued to conduct ground attacks to support the advancing UN forces. The B-29 forces also began strategic operations against North Korea, designed to cripple its warmaking capacity. These attacks were targeted on North Korean industry and its transportation systems. All of these operations continued with no real hindrance from the North Korean Air Force, which had largely been eliminated by that point. As the major air fields near Seoul, particularly Kimpo and Suwon, were recaptured, repairs were undertaken and American air units, including jets, began to base there. As UN forces drove towards the Yalu River, the triumph and domination of American air forces seemed total.[11]

This dominance on the ground and in the air made the shock inflicted by the Communist forces in November and December 1950 all the greater. As UN ground troops reeled under the assault of more than 50 Chinese divisions, the American air forces received a blow almost as shocking, if somewhat less damaging. American planes began to encounter a Russian-built fighter, the MiG-15, in combat. The Russian aircraft was being operated by the Chinese Air Force from Chinese airbases across the Yalu, particularly the Antung complex near the extreme western portion of the Korean/Chinese border. Although the first encounters between the MiG and FEAF F-80s resulted in victories for the American planes and no losses, it was obvious that in most respects the new Communist fighter badly outclassed all the UN aircraft operating in Korea.[12] This prompted an urgent request from FEAF for the latest American jet fighters to match

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the MiG. The Air Force, which had up to this point kept all of its latest aircraft in the United States to protect the country from the Soviet menace, was persuaded to send two additional fighter groups to Korea. This was both to counter the threat of the MiG and to evaluate the performance of the latest American fighters in combat. One of these two new groups was a fighter-bomber group equipped with F-84Es and the other was a fighter-interceptor group equipped with F-86As.[13]

These two new groups arrived in Japan in early December, and then transferred to Korea. They began operations by mid-December, scoring some victories over the MiGs. They did not remain in action for long, as their bases were once again overrun by Communist forces, forcing their withdrawal back to Japan. As the Chinese forces advanced, few encounters with the MiG were recorded, as the MiGs were still based solely in China, and they had a combat range much shorter than even the American jets. During the long retreat south, American ground attack missions continued to wreak havoc on the advancing Communist armies and their supply train, enough to force them to move mainly at night but not enough to prevent them from pushing over the border into South Korea again.[14]

After General Ridgeway assumed command of the 8th Army and first blunted and then stopped the Communist advance, the tide began to turn yet again. During this period, one of the major operations for the American air forces was to stop a Communist plan aimed at extending the range and influence of their airpower. The Communists made a considerable effort to rehabilitate several major airbases in North Korea, especially Sinuiju, Sinanju, and Pyongyang, in order to base MiGs and other modern combat aircraft there. This would give the MiGs, especially, the ability to contest the airspace over the ground combat zone, which their limited

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range prevented them from doing from their bases in China.

The bases in China were officially off limits as targets for American combat operations, but no such restrictions applied to the Korean airbases. FEAF understood that if the Communists managed to push the influence of their airpower further to the south, the UN forces would lose one of their major advantages in the struggle. So sustained and systematic efforts were made to make these Korean airfields unusable for combat operations. Despite occasional heavy losses, these efforts were completely successful, and despite strong defenses and repeated attempts by the Communists for the rest of the war to repair and use these bases, UN aircraft continued to keep them unserviceable. Through the end of the war, only the Communist bases across the Yalu in Manchuria were capable of supporting significant combat operations.[15]

These attacks on the North Korean airbases brought American aircraft once again into combat with the MiG. So frequent did encounters with the MiG become that the entire northwest corner of Korea became known as "MiG Alley," a place where combat with the MiG was highly likely. The MiGs had a number of advantages in these combats. Not only did they have an often overwhelming numerical advantage and operated from bases that were immune to attack, but they also had one of the most important advantages for a fighter: altitude. Designed as an interceptor, the MiG could operate at altitudes as much as 10,000 feet above the best altitude of the F-86A. Since the MiGs could take off and climb unmolested from their bases, this altitude advantage gave them the ability to initiate combat at will, on their terms.

Although UN Fighters, especially the F-86, continued to inflict more damage on the MiG than they received, the MiGs did make it imperative for all bombing and reconnaissance missions in MiG Alley to be escorted. Ultimately even this would not be enough to protect UN bombers.

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A B-29 mission in MiG Alley to attack the Korean end of bridges across the Yalu, conducted on 23 October 1951 by only 8 B-29s, was escorted by 55 F-84s and 34 F-86s. An estimated 100 MiGs engaged the F-86s, preventing them from protecting the bombers. Another 50 MiGs then went after the bombers, using their high speed to make single passes through the formation, which prevented the F-84s from interfering with the combat, despite their best efforts. Three B-29s were destroyed outright, and all but one of the surviving bombers had significant battle damage, including dead and wounded crew members.[16]

Other missions during the month of October raised the total losses of B-29s during that month to eleven, with a total of 55 crewmen dead or missing. Given the relatively small number of B-29s available, and the limited pool of trained crew members, these losses were unacceptable. The B-29s were subsequently limited to night missions only, which limited but did not eliminate the losses they suffered. The B-26s likewise were restricted to night missions when venturing into MiG Alley. Virtually all bombing missions beyond the line of ground combat were flown at night by 1952. This was partly to avoid the MiGs if the bomber had to venture into MiG Alley, but also largely because the Communists had begun to conduct all movement at night. The slower F-51 was kept out of MiG Alley entirely.[17]

During 1951, the Communists began to conduct air operations at night as well, although in much more limited numbers than the UN. These took the form of nighttime harassment raids by individual aircraft, almost always Russian-built Po-2 biplanes. One such raid, targeted at Suwon on 17 June 1951 managed to destroy one F-86 and seriously damage eight others, more damage than the entire MiG force had inflicted up to that point. Significant efforts and resources were put into combating "Bed Check Charlie," as these raids became known to UN troops, but without

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much success.

The Po-2's top speed was slower than the stall speed of almost any of the aircraft that could be used to intercept it. An "obsolete" fabric-covered biplane that had also been used to great effect by the Russians flying similar missions during World War II, it could fly low and slow, and would fly down steep valleys, below UN radar coverage. The Air Force, the Navy, and the Marines made considerable effort to intercept these nocturnal nuisances, with limited results. The F-82 Twin Mustang had largely been replaced in the Air Force by the F-94B at this point, and the F-94 was simply incapable of going slow enough to actually engage the Po-2. One F-94 managed to do so by lowering its landing gear and flaps, and shot down the intruder. However, the F-94 went into a stall and crashed immediately afterwards, so this tactic was not repeated.

The Navy and Marine Corps also went after the night intruders, initially with radar-equipped F4U Corsairs and F7F Tigercats, and later with F3D Skynights. Again, they managed a few victories, but had difficulty engaging the biplane because of its low speed and high maneuverability. None of these efforts were sufficient to stop or even seriously disrupt the nighttime harassment raids.[18]

Beginning in the spring of 1951 and continuing throughout the rest of the war, the primary mission for UN air forces became the interdiction of enemy supplies and reinforcements, the destruction of the North Korea's transportation system, and tactical ground support missions in support of the front line troops. This did not mean that strategic targets or enemy air bases were abandoned, but most of the worthwhile strategic targets in Korea were reduced to rubble fairly early in the war, and the raids on the air bases were occasional rather than continuous. This interdiction effort was termed Operation Strangle, which turned out to be an unfortunate word

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choice. It implied an ability to choke off enemy supplies, which unfortunately for the UN and the Air Force never even came close to being realized.

The interdiction efforts were made against enemy troop concentrations and vehicles, as well as bridges and railroad tracks. Once the front lines stabilized near the 38th Parallel, there were no exposed enemy troop concentrations available to be attacked, as the Communist combat forces were heavily dug in. Enemy vehicle traffic quickly shifted to nighttime operations, and so did many of the interdiction missions, especially those flown by B-26s. These nighttime missions had limited success, as it was extremely difficult to spot vehicles in the dark, and the rugged Korean countryside and increasingly heavy flak defenses made flying low hazardous.

Likewise, although the attacks on rail system and bridges were reasonably successful, the Communists proved adept at rebuilding such damage almost as quickly as it occurred. They also developed great skill at camouflage and deception, and increased flak defenses to very high levels. All of this made the interdiction efforts difficult, hazardous, and indecisive. A great many vehicles and bridges, as well as many miles of railroad track, were destroyed by the interdiction missions. But these efforts were only an inconvenience to an enemy that was largely immobile, heavily dug in, and whose ultimate sources of supply were free from interference outside the country.[19]

During the first half of 1951, it became increasingly obvious that not only was it impossible to win control of the air with the single group of F-86s, but that there was a serious risk of losing control of the airspace, at least over MiG Alley. And if the Communists could win control of the air over MiG Alley, it would provide them an opportunity to rehabilitate air bases in the region, extending their air cover southward and repeating the process. Making the situation worse was the grave shortage of spare parts needed to keep the existing aircraft flying.

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Serviceability rates for the F-86 equipped 4th FIW often dipped below 50%, with many aircraft unusable for weeks, simply due to lack of parts. Colonel Thyng, commanding officer of the 4th FIW, after making every possible effort to obtain more aircraft, spare parts, and trained personnel, finally risked his career by courageously sending a message over the heads of his local superiors and the supply officers who had been frustrating his efforts directly to General Vandenberg, the Air Force Chief of Staff, detailing the problems. At the conclusion of the message he included the following sentences: "PERSONAL TO VANDENBERG FROM THYNG. I CAN NO LONGER BE RESPONSIBLE FOR AIR SUPERIORITY IN NORTHWEST KOREA."[20]

Colonel Thyng was not the only officer in the theater to be concerned with the situation. General Weyland, commander of FEAF, had been pleading for more F-86s, and more advanced models to replace his aging F-86As, but the Air Force, more concerned with defending the continental United States against an essentially non-existent air threat, refused to send any more planes. Finally, the losses of October, combined with Colonel Thyng's earlier telegram, prompted General Vandenberg to order another 75 Sabres to Korea. These would be used to upgrade the 4th FIW, as well as convert the 51st FIW from F-80Cs to F-86s. The newly converted 51st FIW was to be commanded by Colonel Francis Gabreski, one of the top scoring American aces of World War II, with 28 confirmed kills. He would go on to score an additional 6.5 kills in Korea, to become one of only three American pilots to rank as an "ace" in both wars (Colonel Thyng was another).

Most of the new F-86Es went to the converting 51st FIW, with the 4th FIW receiving them in smaller numbers over many months. Although the new Sabre model with the "flying tail" went some distance to evening the odds between the UN and Communist equipment, the Russians

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too were improving their machines. About this time, American pilots began to report encounters with MiGs that seemed to possess superior performance. These were, in fact, the MiG-15*bis*, an improved model with a considerably more powerful engine, giving it even better acceleration and climbing abilities.[21]

Eventually the F-86F model would be sent to Korea, further evening the odds between the two planes. The F-86F-30, with the 6-3 hard wing, finally gave the Sabre equal or superior performance over the MiG in virtually every category, as well as equal altitude performance, and allowed the American pilots to go after the MiGs even more aggressively. Eventually an additional fighter group would be equipped with the F-86F, to be operated as a fighter-bomber in the ground attack role. Additional F-84s, including the more advanced G model, were also sent to Korea, where they performed as fighter-bombers, since they were incapable of functioning effectively as air superiority fighters in combat against the MiG.

During the last six months of the war, as both sides attempted to reach an armistice, the F-86 pilots became much more aggressive. Although flights over the Yalu were always officially forbidden, a number of the more aggressive pilots had throughout the war had been engaging in "hot pursuits" across the river, even to the enemy airbases. A number of F-86 pilots later claimed that they shot down quite a few MiGs more than their official scores gave them credit for, but as they were over enemy territory in violation of orders at the time it happened, they could hardly submit claims. One such pilot was 1st Lieutenant Bill Ginther.

> Struggling to get away, the enemy pilot dived to earth, pulling out just in time to pass along the runway at the crowded Antung airfield. Ginther's gun camera film, as Mahurin later described it, showed 'row after row of MiGs lined up on either side of the

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> runway' so that 'it appeared that the F-86 was flying even below the tops of the MiG tails.' While enemy technicians stood on the MiGs watching, Ginther shot down his foe and somehow got away unscathed. Straight after returning to base he burned his film after its one and only private showing.[22]

In the early months of 1953, as the war dragged on and the armistice negotiations appeared to be deadlocked, plans were drawn up in the Pentagon to expand the war if the negotiations collapsed. These plans envisioned taking the war to the Chinese, as well as attempting to break the stalemate on the ground in Korea. This would be accomplished with amphibious invasions on both sides of the peninsula at its narrowest point, near Pyongyang, and major air attacks on both Korean and Chinese targets with nuclear weapons. As part of this more aggressive posture, attitudes were unofficially relaxed about violating Chinese airspace.[23]

Although it was still officially against orders to attack aircraft across the Yalu, it became more acceptable to "wink" at pilots who did it. A fair amount of unofficial air combat took place over Manchuria the last few months of the war, and apparently helped persuade the Chinese government that the United States was serious about escalating the war if it didn't come to an end soon. Although it cannot be proven, it seems reasonable that these attacks helped convince the Chinese government to sign an armistice. The death of Joseph Stalin and the withdrawal of the Soviet Union from its clandestine but controlling role in the conflict was doubtless another significant factor.

The Korean War had been a costly experience for the United States Air Force. When the war ended, the Air Force had lost in Korea, to all causes, 1,466 aircraft, the equivalent of twenty combat wings, almost 1/4 of the total front-line combat strength of the entire Air Force in 1950.

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For those losses, FEAF claimed to have destroyed 976 aircraft, 1,327 tanks, 82,920 vehicles, 963 locomotives, 10,407 railway cars, 1,153 bridges, 8,663 gun emplacements and 593 barges or boats. The very nature of air combat produces exaggerated damage claims, in some cases grossly so, yet these numbers do indicate a serious and sustained effort on the part of the Air Force. The newly-independent Air Force felt a justifiable pride in its accomplishments during the war.[24]

Yet for all this effort, the Air Force's contribution to the war was not nearly as decisive as they had hoped for (and vigorously claimed). The Air Force's most significant success was keeping Communist airpower confined to China, and not allowing it to expand into Korea. The strategic bombing effort was simultaneously entirely successful and completely irrelevant. Although the damage to the North Korean infrastructure was almost total, since the war effort after 1950 was being carried largely by the Soviet Union and China, it ultimately mattered little. As a counterpoint to this, the American strategic bombing force was revealed to be frighteningly vulnerable. Not only were the older B-29s (and presumably their updated cousins, the B-50s) seen to be completely at the mercy of Soviet MiGs, even with heavy fighter escort, but by inference even the bigger and faster B-36s and B-47s might be vulnerable to such interceptors. General LeMay was also concerned with the loss of "face" suffered by SAC in Korea - if the U.S. strategic bombers were not as invincible as they had been portrayed, that could have major repercussions on everything from foreign policy to defense budgets.[25]

And if the F-86 Sabre had proved to be superior in combat to the MiG-15, that was due more to the high levels of training, skill, aggression, and initiative displayed by the American pilots than to any inherent superiority of their aircraft, despite the claims of the Air Force. On the rare occasions when the MiG pilots were both competent and aggressive, they could and did

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inflict serious losses on American aircraft. It is worth noting that the two highest scoring aces of the Korean War were not American at all, but Russian, despite the relatively limited combat time allowed individual Russian pilots.

Before examining the specifics of the performance of American jet fighters in combat, a few points about the overall experience of the air war in Korea need to be noted. These factors affected all air operations, but were especially important for jet aircraft.

Korea was a far from ideal environment for air force operations. At the time of the war, both portions of the peninsula were just beginning to recover from half a century of exploitative Japanese occupation. Both halves of Korea were very underdeveloped in terms of a modern infrastructure. The climate was quite brutal. In many ways, the war in Korea had similarities to the American experience in the Pacific Theater during World War II. However, unlike most of the islands on which the U.S. Army and Marines fought and died during the struggle with the Japanese Empire, Korea had a large civilian population and most of the flat land was already in use, under cultivation. This meant that American engineers could not simply select the most favorable location and build all the airbases they needed. The South Koreans were American allies, not simply the indigenous people who happened to be in the way of a global struggle, which meant that the needs of the Koreans had to carefully factored into such decisions. This limited the number of airbases the American air force had to operate from.

Not only were there few airbases, but even the largest of them, such as Suwon and Kimpo, were, by American standards, small and primitive. They were overcrowded and uncomfortable to live and work in. None of them even had any permanent buildings until late in the war. Not only did this mean that the pilots and service crew slept in tents or crude huts, but it meant that there

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was no place to take the aircraft out of the elements to be worked on. Much of the maintenance delays affecting American planes, especially in the early days of the war, was simply a shortage of the necessary tools with which to do the job and the brutal environment in which the work had to be done.[26]

Only the largest of the airfields in Korea had paved concrete or asphalt runways, and even these fields had only packed dirt strips for revetments and taxiways. Since the jets needed the paved runways, they all had to be based at the few airfields that they could operate from, which led to very crowded conditions for both planes and personnel. The unpaved taxiways and revetments had to be covered with Pierced Steel Planking, also known as Marston Matting. These perforated steel strips, first used during World War II, allowed the creation of a reasonably hard and level surface over bare dirt, and were quick and easy to emplace. Balancing these positive attributes, the strips could be thrown out of level fairly easily, creating uneven and dangerous surfaces, and because of the high taxi speeds of the jets, the planking caused excessive wear on their tires, causing occasional blowouts and necessitating tire changes much more often than would have been the case at an American base.

The weather in Korea was another obstacle to effective air operations. A common saying among those who served in Korea was that there were only three seasons - summer, early winter, and late winter. Summer was dry and blisteringly hot, and worse, because of the packed dirt elements of the airfields, raised huge dust clouds that were ingested by the aircraft every time they operated. All that dust was highly abrasive, and wore out the jet engines even faster than normal. This meant even more frequent engine repairs and replacements, which created an even heavier maintenance burden on the already overworked maintenance crews.

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If the winter brought a respite from the heat and the dust, it created its own problems. Korea, although not as far north as much of the continental United States, is subject to the frigid winds that blow down out of Siberia, and so can become bone-chillingly cold in the winter. Frequent snowfall exacerbates the difficulties caused by the temperature. Since there were few permanent structures in which to perform all the necessary maintenance chores, all such jobs had to be done outside, in blizzards and sub-zero temperatures. Before starting the jet engines, it was necessary to warm up the various liquids in the engine, especially the lubricants. This meant preheating the engines before starting them by pumping large quantities of hot air into them from mobile air compressors.[27]

Causing still more grief for the hard working maintenance crews was the chronic shortage of spare parts, tools, and accessories needed to keep the aircraft flying. Combat aircraft are subject to far more stress than civilian aircraft, and it was expected that parts would wear out and need to be replaced on a regular basis. For this reason, most aircraft production contracts during this period required the company to produce extra parts of all types, usually 25% above the number of complete aircraft called for by the contract. But to be used, those parts had to be available to the mechanics. During much of the war, the shortage of spare parts was endemic, and affected all the air combat units in Korea. Those units based in Japan and other island bases had a much easier time, with a more benign environment, better facilities, and higher stocks of parts available. Commanders in Korea often had to beg and plead for the parts needed to keep their airplanes flying, and frequently ran into trouble dealing with Stateside supply bureaucracies. Difficulties of this sort eventually drove Colonel Thyng to bypass the entire process and risk appealing directly to Vandenberg.

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It was not only a shortage of extra parts, but of ordnance and operational equipment that hindered the effectiveness of air units. The consumption of external ordnance, such as bombs, napalm, and rockets was extremely high in Korea. During the early portions of the war, limited stocks of these materials restricted the number of sorties that units could fly. A similar problem, especially for the F-80s and F-86s, was a shortage of external fuel tanks. For the F-80s, initially based in Japan, their standard drop tanks simply didn't hold enough fuel to enable them to fly to Korea and carry out a combat mission. A solution was found by two lieutenants, who cut apart the standard tank and spliced the center section from a Fletcher streamlined tank in between the original nose and tail sections. The new fuel tank, named the Misawa tank, after the air base where it was created, gave the F-80 an extra hour's endurance, a vital improvement for a relatively short-legged aircraft. The Misawa tanks would be standard on most F-80s throughout the war.[28]

Once the F-86 was committed to action, it had difficulty with fuel tanks also, although of a different nature. The design and production of the "Combat" drop tanks for the F-86 had solved some of the technical problems that had affected earlier models, but there were never enough of the tanks. Combat tanks were not a cheap, easily produced generic fuel tank (such as the reinforced and treated paper drop tanks used by the 8th Air Force in England during World War II), but a precision built component. These tanks were specially produced by North American (and later by a few Japanese companies). The tank shortage got worse once additional units of F-86s were committed to combat. Throughout the war, it was not unusual for F-86s to fly combat missions with only one drop tank, because there simply were not enough to use two.[29]

Compounding the problem was the fact that pilots always dropped the tanks before going

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into action, even though with the combat tank this was not necessary. It had been demonstrated that even when full, the combat tank imposed no penalty in drag or maneuverability on an F-86, but the pilot's instinctive reaction in combat was to get rid of extra weight. This response easily overcame any consideration of bringing back the fuel tanks. That it was not necessary to jettison the tanks to do well in a fight was demonstrated by then-Captain James Jabara, who in a dogfight on 20 May 1951 managed to shoot down two MiGs despite being unable to jettison one of his drop tanks.[30]

In examining the performance of American jet fighters in Korea, one approach would be to present each aircraft type, and discuss its performance in various roles. This would quickly become repetitive, as most jets in Korea performed the same type of missions. A more productive method would be to present the various types of missions performed by the jets, and examine the successes and failures of the different aircraft when undertaking them. There were four basic types of mission performed by American jet fighters in Korea - interception, bomber escort, ground attack/interdiction and air superiority. Each will be examined in turn, with consideration of the various aircraft performing the mission and their various records.

The first type of mission to be considered is interception. This was probably the least significant of the jet missions performed during the war. Interception involved engaging enemy aircraft in combat before they could attack friendly forces, and therefore required that the enemy air force be performing offensive combat operations. During the first few months of the conflict, there were some interceptions of North Korean aircraft, although these were usually accidental or the result of attempting to protect a particular objective. Against the North Korean aircraft, these interceptions were usually very successful. This resulted from a variety of factors, including the

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relative obsolescence of the North Korean aircraft and the much greater experience and training of the American pilots.

Once the North Korean Air Force was destroyed, daylight interceptions basically ceased. Although the North Korean Air Force eventually returned to the conflict, with a small number of MiG-15s in 1953, their role was identical to that of the Russian and Chinese MiGs, and provided no need for interceptions. The Soviet Union did equip the Chinese Air Force with other modern combat aircraft besides the MiG-15. Both piston and jet powered ground attack, transport, and medium bomber aircraft were also found in the Chinese Air Force. Repeated efforts to base these planes at bases in North Korea only led to their destruction on the ground by the American air force. Had the Communists been successful in extending the reach of their MiGs, it was likely that these other types of aircraft would have been used in the fighting. As it was, the Communists showed a great deal of common sense by not sending these aircraft on unescorted combat missions into areas dominated by American air power, where they almost certainly would have suffered severe losses.

Although the American restraint in not attacking Chinese airbases is one of the better known examples of the decision to limit the conflict to Korea, the Soviets, in particular, exercised similar restraint. A number of the major American air bases in Japan would have been vulnerable to attack by Russian or Chinese aircraft, but no such attempts were ever made. Despite a number of incidents near Japan involving Soviet and American planes, with a few American aircraft losses, no Russian planes were ever shot down anywhere but over Korea, southern Manchuria, and the surrounding waters.

The other type of interception missions were those flown to attack the night harassment

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aircraft, the "Bed Check Charlie" Po-2s. For the Air Force, these missions were flown exclusively by F-94s, and must be judged to be failures. The same could be said about the Navy and Marine's efforts to do the same thing. Although the F-94s did manage to down a few Po-2s, they suffered almost as many casualties of their own in the process. In fairness to the F-94, this was hardly the type of mission they had been designed for. Intended to attack large, fast, and high-flying strategic bombers, asking them to intercept small, agile, low, and slow fabric-covered biplanes was hardly a fair test of their abilities. It was rather like going after mosquitos with a shotgun - it was possible to get one, once in a while, but only at rather serious risk to life and limb.

The Po-2s not only had the ability to fly below American radar cover, thus penetrating the defenses fairly easily, but they were a small radar target themselves. Their tubular and fabric construction did not produce a very large radar signature, which made it even more difficult for the F-94s to generate an intercept. The fact that an F-94 had to risk a potentially fatal stall just to slow down enough to take a shot at the biplane added another layer of difficulty to the process.

Although the jet powered F-94 was undoubtedly the wrong aircraft to attempt such missions, the Air Force's "newer is better" approach to aircraft meant that it was the only one available. Since the F-94 had replaced the F-82, the Air Force refused to even consider bringing the F-82 back into combat, and retired the F-82 as quickly as possible. In fairness, though, it is doubtful that any aircraft in the American inventory would have been very successful in this particular mission. The Marines tried to use the F7F Tigercat, a contemporary of the F-82, for similar intercepts, and had exactly the same problems - it was too hard to locate the target, and the plane flew too fast to easily get a shot at the intruder. The Tigercat was a World War II design, and the same problems would undoubtedly have affected other World War II era radar-

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equipped American planes, such as the P-61 Black Widow. The Americans were never able to stop or even seriously interfere with the nighttime harassment raids throughout the war.

The next mission to be considered is bomber escort. This mission was performed in earnest for less than a year - between January and December of 1951. Prior to this time, bomber escort was not considered necessary. The piston-engined Yaks of the North Korean Air Force would hardly have been able to catch the fast and high-flying B-29s. Even if they had been able to, the lightly armed fighters would have had great difficulty inflicting serious damage without being shot up themselves. Even the smaller B-26s could usually hold their own against the propeller fighters. Once the North Korean Air Force was eliminated, of course, there was little need to escort the bombers. Not until the end of 1950, when the MiG-15 made its appearance, did the need to escort bombers appear.

For a short while after the introduction of the MiGs, the American military was too busy retreating down the peninsula, out of the MiG's range, to have to worry about it. Further, the fighters that might have provided the escort, the F-84s and F-86s, were transferred to Japan, and so were unavailable. When the front lines stabilized and then began to move north again, the Air Force began to conduct offensive operations in North Korea again. As many of these missions were within the range of the MiGs, the need for escort had to be considered.

Initially only a modest number of escorts were assigned to bombing missions. The number of fighter escorts began to increase as the response of the MiGs became more aggressive and effective. The Communists began to build an increasingly effective and long-ranged radar network north of the Yalu, which further improved their ability to intercept UN raids. Since the MiGs had the advantage of superior altitude and greater numbers, when they did intercept a

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mission they could inflict devastating losses.

As far as the ability of UN jet fighters to provide an escort for bombers, only the F-86 had the performance to take on the MiG in a fight. Attempts to use F-84s were generally unsuccessful. In the raid mentioned earlier in this chapter, it is significant that the Communists felt that 100 MiGs were necessary to neutralize only about 35 F-86s, but that 50 MiGs could freely attack the bombers despite the presence of over 50 F-84s. It is worth noting that in the after-action reports, the surviving bomber crews were unanimous in their praise of the efforts of the F-84s to defend the bombers, as well as their judgement that they were completely unable to do so. The conclusion of the bomber crews was that it would have taken at least 150 F-86s to provide any reasonable protection for the bombing raid (of just 8 bombers!).[31]

Since daylight bombing raids were largely discontinued in MiG Alley shortly after this disastrous mission, the need for fighter escorts likewise disappeared. It was clear that American jet fighters were failing in the bomber escort missions, for a variety of reasons. Among these were the superior performance of the MiG-15, the limited numbers of American fighters available for the missions, and the highly restrictive Rules of Engagement (ROE), which prevented the Americans from going after the source of the Communist's airpower. The shift to night bombing in MiG Alley was a tacit admission by FEAF that it simply could not protect American bombers during the daylight. Even later in the war, as more advanced and numerous models of the F-86 arrived in the theater, it was still not considered practical to resume daylight bombing. If the UN now had 150 late model F-86s in Korea, it was estimated that the Communists had over 1,000 MiGs in Manchuria. Even if the F-86s could hold their own in aerial combat, that was no guarantee that they would be able to protect bombers. This revelation of the vulnerability of

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SAC's bombers prompted SAC to largely abandon the idea of bomber escort and to begin searching for bombers that could minimize the possibility of interception by fighters, a path that would lead to such designs as the XB-70, B-1, and B-2 bombers in later years.

The most significant of all the missions flown by American jet fighters, whether evaluated based on the number of sorties flown, the destruction caused, or their impact on the outcome of the war, was the ground attack/interdiction mission. Beginning with F-80s in the opening days of the war, these missions continued throughout the conflict. Jet fighters were used to deliver a wide variety of ordnance to ground targets, from bombs to napalm to rockets. Operating both over the front lines as well as many miles behind enemy lines, these aircraft went after a variety of targets - enemy troops, fortifications, guns, vehicles, tanks, boats, bridges, and trains.

The success of American jet fighters performing these missions varies depending on which criteria are used to evaluate them. The Air Force was highly enthusiastic about the success of their jets in these missions, claiming much better results for the jets than for prop fighters performing the same mission. It is important to realize that the only significant criterion the Air Force used to judge such success was the survivability of the plane performing it. It is certainly understandable that the Air Force, in competition with the Army and Navy for budget dollars, should be reluctant to lose any of its increasingly expensive aircraft or its highly trained pilots. If minimizing losses is the overriding operational concept, then obviously the most survivable aircraft is the most successful one. This attitude also explains the Air Force's fondness for interdiction missions, which took place well behind enemy lines, where the defenses were weaker, than for direct combat support on the front lines, which exposed the plane to a great deal of enemy firepower.

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Regardless of where they were carried out, ground attack missions were the most dangerous mission carried out by the Air Force. Of the almost 1,500 aircraft lost by the Air Force in Korea, over 800 were lost as a result of combat. Of that number only about 140 were lost in air combat, that is, shot down by enemy aircraft. Close to 700 American Air Force aircraft were lost to ground fire. The numbers from the Navy and the Marine Corps are even more lopsided, as these aircraft concentrated almost exclusively on ground attack missions. Of the 541 Navy and Marine Corps aircraft lost in combat, only 4 were lost to enemy aircraft. The other 537 were destroyed by ground fire.[32]

As the Air Force evaluated the success of its jet fighters on ground attack missions, they decided that the jet fighters were twice as effective as prop fighters, based on the fact that loss rates per sortie were twice as high for F-51 equipped units than for jet equipped units performing the same mission. This evaluation was not completely fair to piston engined planes, as even back in World War II it was recognized that the liquid cooled P-51 was a good deal more vulnerable to ground fire than was an air cooled aircraft such as the P-47. In fact, unit commanders in Korea requested F-47s (still available, although in storage, in the United States) to replace their F-51s, but were refused.

When performing ground attack missions, jet fighters did have some advantages over piston planes, as a result of the nature of the jet engine. Lacking the vibration and the torque of the big piston engines, jet fighters tended to be much more stable weapons platforms, easier to aim and hold on target. This (in theory) made them much more accurate when attacking ground targets. Unfortunately, this advantage was largely neutralized by the much higher speed of the jets, which not only gave them higher survivability but also much less time to locate and aim at the

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target, and made it much more difficult to correct aim during an attack run. So while a jet fighter may have been easier for the pilot to use and more likely to survive a ground attack, it did not mean that his attack was more successful or accurate than that of a piston engined airplane. So any attempt to define success at ground attack must decide which is more important - that the airplane return intact, or that the weapons strike the target.

The Air Force's emphasis on surviving ground attack missions, even at the expense of the accuracy of the attack, was not greatly appreciated by the soldiers on the ground. Complaints about the Air Force's lack of enthusiasm for the ground attack mission had begun well before World War II, and show no sign of letting up, even today. But in Korea the issue was complicated by the presence of Marine divisions. Each Marine division had a permanently attached Marine Air Wing, intended primarily to provide ground support for the division. This arrangement was created largely because a Marine division lacked the number and size of artillery pieces normally allocated to an Army division. Intended for rapid amphibious transportation or assault, it was impractical for the Marines to have large, unwieldy artillery trains attached to their divisions. Instead, the Marine Air Wing was intended to be "flying artillery."

To fulfill that role, Marine pilots often were willing to take substantial risks in order to put their ordnance directly on target, even in the face of heavy ground fire. This tendency was reinforced by the fact that the Marine fliers belonged to the same branch of service as the troops on the ground they were supporting, which gave them greater incentive to take risks when flying their missions. Marine pilots often used the more dangerous dive bombing technique, as opposed to the easier glide bombing, because dive bombing made it easier to hit the target. Given the purpose and attitudes of the Marine pilots, it would have been almost impossible for the Air Force

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pilots not to have suffered in comparison.

The desire of Army troops to have the Air Force perform ground attack missions in the same fashion as the Marine pilots caused considerable grief for the Air Force. Not only did they have to deal with this attitude from army commanders in Korea, but newspaper headlines like "Give Us Flying Marines," appearing in the *Chicago Tribune* did not make relations between the Army and Air Force any more cordial.[33] It was only natural that the Army, committed to a remorseless struggle over rugged ground, should want all the support it could get. It was much easier to convince a soldier that the plane dropping a bomb on enemy lines less than a mile away was helping the war effort than if that same plane dropped its bomb on a railroad track 50 miles behind enemy lines where he couldn't see it. The fact that after 1951, the enemy was so well dug-in that aerial bombardment was relatively ineffective against their positions likewise cut no ice with army troops. The logistic and command impossibilities of providing each Army division with its own dedicated ground attack aircraft in the manner of the Marine Corps were also of little comfort to ordinary soldiers.

In this particular argument, there was merit in both positions. There is no question that Air Force planes destroyed a great deal of enemy material well behind the front lines, and that they made it more difficult for the enemy to move troops, equipment, and supplies. On the other hand, these interdiction missions were never as successful as the Air Force hoped or claimed, and never seriously detracted from the ability of the enemy to fight. However, even if the Air Force had done what the Army wanted, and devoted itself to close support ground strikes on enemy front line positions, the evidence suggests that this would not have significantly eased the burden of the ground soldiers, and it undoubtedly would have cost the Air Force even more aircraft.

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The F-80, F-84 and F-86 all participated in ground attack missions in Korea. Both the F-84 and F-86, as newer and more 'glamorous' airplanes, have received most of what little attention has been given to aircraft performing this mission. But the F-80 was probably the most important of the Air Force jet fighters doing ground support work. The F-80 performed this mission far longer than either of the other two aircraft, it could carry a heavier bomb load, and because it was an older and slower aircraft, it was probably a more accurate bomber, as well. The F-80 could carry up to four 1,000 pound bombs, two on the normal bomb mounts beneath the wings and two in place of the wingtip tanks, although this configuration severely limited its range. Both the F-84 and F-86 could carry no more than two 1,000 pound bombs. Both the F-80 and F-84 made extensive use of JATO when loaded with bombs or other external ordnance.

The F-84, brought in after the MiG was encountered, was preferred over the F-80 for ground attack missions, especially if those missions were carried out in MiG Alley. Although the F-84 was not able to win many encounters with the MiG, it was more likely to survive close combat with one, especially at lower altitudes. In any case, ground fire was far more dangerous for a plane making these types of attacks, and the faster F-84 was considered more survivable than the slower F-80. Eventually, the latest G models of the F-84 were brought to Korea to serve as ground attack aircraft.

The final ground attack fighter was the F-86, specifically the F-86F-30. Although both the F-80 and F-84 had been designed from the outset to carry and deliver external ordnance, the F-86 had been designed primarily as an air superiority fighter. The original provisions in the F-86 design for carrying external ordnance were very limited, as the ability was not initially seen as very important for the aircraft. Only later would the F-86 be modified to carry useful amounts of

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external weapons. Both the slatted and 6-3 hard wing versions of the -30 were used as ground attack machines. An additional pylon was added under the wings, inboard of the pylon for the drop tanks. A single bomb could be carried on this pylon, up to 1,000 pounds. Ground attack F-86s began operating at the beginning of 1953, and by the end of the war, the bomb-carrying F-86 had become the favorite of the Air Force, who considered it superior to both the F-80 and F-84 in the ground attack mission. Again, the only significant criteria the Air Force used to make this evaluation was survivability. An F-86, once the bombs were dropped, was more than capable of holding its own against a MiG, and its higher speed, combined with the resultant need to drop its bombs from a higher altitude than the other planes, made it less vulnerable to ground fire.

The Air Force's judgement of the F-86 as the best ground attack machine did not take into account that when armed with bombs, the F-86's range was much shorter than either the F-80 or F-84 with the same bomb load, nor the fact that the F-86 was not designed to accommodate JATO units to assist on take off. Also, the higher speed of the F-86 made it even less accurate when actually dropping its bombs. In every category but one, the F-86 would have been judged as the poorest performer at ground attack missions. But since the one category in which the F-86 excelled was mission survivability, this made it a favorite of the Air Force.

Both the Army and the Air Force have criticized the other's attitudes about the ground support mission, a practice that dates back to well before World War II, and shows no sign of fading away. The Army charges that the Air Force is more concerned with the safety of the airplane and with performing other missions than it is with actually putting the ordnance down on target to help the ground pounders. The Air Force, in turn, charges that the Army does not understand the complexities of target identification and accurate attacks from a fast moving

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aircraft. Both arguments have a good deal of truth to them, and a resolution to the argument is not likely any time soon. It is not disputed, though, that ground attack missions, especially on heavily defended targets, rank right at the bottom of the Air Force's list of preferred activities.

In fact, some sentiment exists in the Air Force not to conduct such missions at all, or at least to conduct them at high enough altitudes that successful ground fire is unlikely. This tendency can be seen in the fact that the rugged and powerful A-10 ground attack aircraft, which performed so superbly during the Gulf War, has been partially replaced by a ground attack capable version of the F-16. The Air Force had intended to retire the A-10 prior to the Gulf War, but the impressive performance of the aircraft caused a reassessment. One of the Air Force's principle objections to the A-10 is that the aircraft is not intended to perform missions other than ground support, making it much less versatile than a multi-mission fighter.

With regard to the ground attack/interdiction mission for jet fighters in Korea, the Air Force claimed great success, and produced small mountains of statistics and kill claims to support those claims. All jets were to claimed to be inherently superior to piston aircraft when performing ground attack missions, entirely because they were more likely to return. Of the F-80, F-84, and F-86, the Air Force judged the F-86 the best ground attack machine, again because on a per sortie basis, it was more likely to come home intact. If viewed in terms of tonnage dropped, targets destroyed, or the ability to actually hit ground targets with external ordnance, the F-80 must be ranked as the most effective of the jet fighters in this role.

One final note regarding the Air Force and jet fighter-bombers. Largely as a result of the lessons of Korea, the Air Force eventually acquired a specialized tactical ground attack aircraft, the Republic F-105 Thunderchief. A big, powerful aircraft, one of the "Thud's" primary virtues,

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from the Air Force's point of view, was its ability to deliver tactical nuclear weapons to the battlefield. Then, during the Vietnam War, the F-105 was discovered to be almost completely ineffective at delivering anything but nuclear weapons, and was found to be largely useless as a tactical ground support aircraft. The planes the Air Force ended up using in Vietnam for ground support work included converted transports, such as the AC-47 and AC-130 gunships, and a piston-engined plane designed for the Navy during World War II, the Douglas AD Skyraider. Ironically, one of the most powerful and useful of all the Air Force's ground attack aircraft in Vietnam turned out to be the mainstay of SAC, the giant B-52 strategic nuclear bomber, performing saturation carpet bombing "Arclight" missions.

The final mission performed by Air Force jet fighters in Korea was also the best known. Air superiority missions - that is, air combat with enemy fighters - dominated the news stories from the Korean War, and provided the American public with what little glamour and excitement could be found in this ugly and frustrating war. Stories of duels between skilled pilots in high performing fighter planes made for entertaining reading, and the exploits and scores of the aces were followed closely by the public.

Very early in the conflict, the F-80 proved that it could completely overwhelm World War II vintage piston engined fighters, but this was hardly a fair measure of the success or failure of American jets in this mission. The true test of the air combat worthiness of American jets would come when they faced the Soviet MiG-15. Therefore, in order to evaluate the performance of American jets against their communist opponent, it is first necessary to examine the MiG-15, to determine why it was such a formidable adversary, and to look at the tactics and operational policies that dictated how this plane was used. With this information, a more accurate assessment

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of the performance of the American machines will be possible.

Aircraft production in the Soviet Union was somewhat different than in most Western nations. Since the Soviet State owned all businesses and factories, Soviet aircraft did not bear the designation of the individual company that produced it, as was the practice in almost every other country. Instead, the designation of Soviet aircraft was based on the bureau that designed it. These OKBs (Experimental Construction Bureaus) were generally know by the names of the leading designer(s), and the aircraft by an abbreviated version of that name followed by a number. Thus, the Yakolev, Ilyushin, and Lavochikin design bureaus were responsible for, respectively, the Yak-9, Il-2, and La-7 aircraft. The design bureau headed by Artem I. Mikoyan and Mikhail Y. Gurevich was known as the MiG bureau, and was responsible for the creation of the MiG-15.

In the West, particularly after the shock caused by the appearance and capabilities of the MiG-15, it became popular to deride the MiG-15 as a "rip-off" of a late World War II German jet design, the Focke-Wulf Ta 183. This was in part because of the Soviet tendency to steal designs for weapons that it wanted but did not possess, and also because few people in America wanted to believe that a "backward" power like the Soviet Union was capable of producing such a complex and capable aircraft on its own. Later evidence, particularly that made available following the collapse of the Soviet state, has proven this belief to be largely erroneous.

There is little doubt that the MiG-15 was heavily influenced by German research and aircraft designs. Although the Soviet Union had been researching jet propulsion in the early 1940s, the overriding demands of the war with Germany put this research on hold until very late in the war. When the war ended, Stalin and the Soviet government realized that their country was considerably behind other developed nations in the field of jet propulsion, and demanded that the

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gap be closed as quickly as possible. Given the penalties for failure in Stalin's Russia, and the ready availability of German materials, it would be surprising indeed if such material did not figure heavily in the design of early Soviet jet aircraft.

The design of the MiG-15 was undoubtedly strongly influenced by German jet fighters, especially the Me 262 and Ta 183. There is a strong overall physical resemblance between the MiG-15 and the Ta 183, in fact. Still, much of the MiG's design was new, and the degree of direct imitation of the German work was probably on about the same level as that of North American's swept-wing design of the F-86. The one thing about the MiG-15 that was an unashamed copy of another design was the engine, although not of a German one. The Soviet RD-45 and RD-45F engines used to power the MiG-15 were complete copies of the British Rolls Royce Nene 1 and Nene 2 engines. The British engines, interestingly enough, had been obtained completely legally, purchased by Soviet representatives direct from Rolls Royce, with the post-war British Labour government's complete approval. Stalin himself commented on the stupidity of this decision, saying "What fool will sell us his secret?"[34]

The MiG-15 was designed from the outset to be a daylight interceptor, intended to take off and climb rapidly to high altitudes, to engage enemy heavy bombers and destroy them quickly. This mission was an unusual one for the Red Air Force, which had largely specialized in tactical fighters optimized for low and medium altitudes, but was considered necessary due to the potential for war with the United States, which possessed a large strategic bomber fleet. In basic appearance the MiG-15 resembled the F-86 quite closely, to the point where in combat American pilots were compelled to paint large distinctive colored bands on the wings and fuselage of their aircraft to enable them to tell friend from foe. The MiG-15 had a roughly cylindrical fuselage,

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with a large, divided air intake in the nose of the plane. The pilot sat under a bubble canopy well forward. The wings were swept to 35 degrees, the same angle as the F-86, although they lacked the Sabre's leading edge slats and were mounted in the middle of the fuselage instead of at the bottom of it. To help improve stability at low speeds, the MiG had two 'fences' on each wing, much like the 6-3 hard wing F-86, only on the MiG the fences ran from the front to back span of the wing, instead of just a few feet as on the F-86.

The swept rudder of the MiG was much taller than the rudder on the F-86, and while the Sabre's horizontal tailplanes were mounted on the fuselage at the base of the rudder, the MiG's tailplanes were mounted about 2/3 of the way up the rudder, to remove them from the turbulent airstream near the rear of the aircraft. The MiG also had air or speed brakes on the fuselage, as did the F-86, but they were much smaller, and located at the extreme rear of the fuselage.

Perhaps the biggest difference between the MiG-15 and the F-86 was in armament. The F-86 had the standard American fighter armament of six .50 caliber machine guns. The MiG, intended to shoot down large bombers, had a much more powerful armament, two 23 mm NR-23 cannon and one 37 mm N-37 cannon. The 23 mm cannon had 80 rounds per gun, and the 37 mm had 40 rounds. The cannon had a considerably lower rate of fire and a great deal less ammunition than the .50 caliber guns of the Sabre, but even one or two hits from them could inflict serious damage on an enemy fighter. Interestingly, the cannon on the MiG were mounted partially outside the aircraft, on the lower fuselage below the cockpit, with the two 23 mm on the left side and the 37 mm on the right. The entire gun mounts were easily removable, allowing easy access to the cannon for repair, replacement, and replenishing ammunition. In fact, it was easier for mechanics to simply remove the empty cannon and replace them with fully loaded ones than for

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them to reload the guns while still attached to the aircraft.[35]

Although the MiG's engine was slightly less powerful than that of the F-86A, (5,005 pounds of thrust vs. 5,200 pounds of thrust) the MiG itself was considerably lighter than the Sabre (10,941 pounds loaded vs. 16,223 pounds loaded) giving the MiG a much higher rate of climb (10,000 feet per minute vs. 7,470 feet per minute) and maximum altitude capacity (50,000+ feet vs. 42,000 feet). The MiG's light weight also made it a quick and maneuverable aircraft. However, the MiG's smaller size meant less space for fuel cells, which meant that the MiG had an extremely limited range, even with drop tanks.[36]

The MiG-15 first flew for testing in 1947, only weeks after the first flight of the XP-86. The MiG-15 entered production in 1948, and was first demonstrated in public at an air show in Moscow that same year. Analysts in the West took virtually no notice of the new fighter, and would be taken completely by surprise when it made its dramatic debut over Korea. It is difficult to account for the West's almost deliberate ignorance of this impressive new aircraft, save perhaps as a form of institutional superiority and a disdain for the technological skills of the "backwards" Soviet Union. Later, of course, this attitude would be completely reversed, with Western analysts fearfully awaiting information on the latest Soviet "wonder weapon."

After only about a year in production, an improved model of the MiG, the MiG-15*bis*, with a 5,940 pound thrust engine, began to enter production. The MiG-15*bis* also had a number of improvements to internal components such as the electrical and hydraulic systems. Eventually, incorporating the experience and lessons of the Korean War, a considerably improved version, designated the MiG-17, entered production, although not until after the Korean War had ended.[37]

The vast majority of the MiGs encountered by UN pilots during the Korean War wore the

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markings of Communist China. Late in the war, some American pilots reported encountering MiGs with different paint schemes and markings, and the assumption was that those aircraft actually belonged to the Soviet Union, although this has not been verified by Russian records. A small number of MiGs also were given to the rebuilt North Korean Air Force, and by 1953, enough Korean pilots were trained on the machine that some entered combat. Since the Chinese communists had not had a country, let alone an air force just a few years previously, the assumption made in America was that not only were the Soviets supplying the Chinese with aircraft, but also undoubtedly with some skilled pilots to train and lead the Chinese air units.

What was not known with certainty (or at least admitted) in the West until quite recently was the scope of the involvement of the Soviet Union in the Korean War, or at least in the aerial portion of the fighting. Stalin not only supplied the Communist Chinese with aircraft and skilled fliers to train their new air force, he also sent entire Russian air units as well. Beginning in 1950 and continuing through 1951, every MiG encountered in combat by the UN was in fact flown by Soviet pilots. The Red Air Force committed an entire fighter corps to China for combat in Korea. Not until 1952 would Chinese-piloted MiGs enter combat, and even then Soviet air units continued to be rotated through the theater. In fact, active Russian involvement in the air war would not end until Stalin's death, shortly before the armistice was signed.[38]

Many of the Russian fighter regiments that rotated through China to fight in the war included combat veterans from World War II, even a number of pilots who had attained ace status during the war. One of the fighter units (324th Fighter Air Division) that served in Korea was commanded by Ivan N. Kozhedub, the highest scoring Soviet ace of World War II (62 kills).[39] In fact, as noted previously, the two highest scoring fighter pilots of the Korean War were Russian.

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Colonel Evgeni Pepelyaev was credited with 23 kills, and Captain Nickolai Sutyagin with 21 kills. (In comparison, the two highest scoring American pilots were Captain Joseph McConnell with 16 kills and Major James Jabara with 15 kills.) Despite this, the performance of MiG units, whether Russian, Chinese or Korean, was rarely up to the standards the US Air Force considered necessary for a combat unit.[40]

One of the greatest difficulties encountered by the MiG units in Korea was the Soviet policy of rotating entire fighter regiments and divisions through a short combat tour in Korea. The entire unit was rotated in and then out again a relatively short time later (between three and nine months). There was very little overlap between units coming in and units leaving, allowing the veterans little time to impart any useful combat lessons. This policy created a steep learning curve for the new units, which cause high levels of casualties in the early engagements. As the unit gained experience, the number of mistakes declined, and the unit began to become much more effective. And that was usually the time they were ordered back to Russia, and a new and inexperienced unit took their place.

The results of this policy were visible even to American pilots, who frequently commented on this cycle of inexperience, gradually growing competence, and then abruptly back to stupid mistakes by their opponents. They also deduced the correct reason for it, but were unaware that the units rotating through the theater were Russian, not Chinese.

Eventually, Chinese pilots began to enter combat in increasing numbers. These units were in fact usually led, even if not actually commanded by, experienced Russian pilots, but the Chinese pilots themselves were very inexperienced, frequently severely malnourished and physically weak, and often very aggressive - a bad combination for a fighter pilot, especially when confronting the

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extremely competent and well-trained Americans. The Koreans, when they became involved with MiGs, demonstrated the same characteristics to an even greater degree.

Given the relative immunity of the bases used by the MiGs, their standard tactics involved taking off when an enemy force was detected, using the fantastic climb rate of the MiG to reach maximum altitude while still on the Chinese side of the Yalu, and then venturing south over the river in a large group. Communist formations throughout the war tended to be much larger and more cumbersome than UN formations. This was due in large part to the lower levels of experience of the Communist pilots, and the Russian emphasis on mass tactics rather than small, mutually supporting formations such as the ones used by the Americans. These large clusters of MiGs were known to American pilots as "bandit trains."

Since the MiG could, until very late in the war, operate at a higher altitude than any UN plane, these large formations could remain aloof from combat if they chose, or dive down on the enemy. They often did not engage in combat unless they had strong numerical superiority or were going after bombers. It was not unusual for a large bandit train to refuse to engage a large alert force of F-86s.

Bandit trains often had at least one, and sometimes several highly skilled and experienced flight leaders. American pilots referred to such leaders as "honchos." In the later stages of the war, it was often a small number of honchos who did most of the fighting, while the rest of the formation either remained above the combat, observing, or else just charged in and got in everyone's way. The tactics employed by the better MiG pilots could be quite effective. Often the bandit trains would be timed in an attempt to catch F-86s at the end of their patrols, heading south and low on fuel. Another highly successful tactic was known to the Americans as the Yo-

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Yo. A small number of MiGs would dive out of a high formation, using their superior altitude to rip through the UN planes, and then using their superior climb rate and the speed from the dive to zoom back up into the larger formation. Such attacks were almost impossible to stop, and if successfully performed, could be devastating, but required a fairly experienced pilot to execute properly.

Despite holding a number of advantages over the F-86, especially early in the conflict, the MiG was by no means a perfect airplane. In most respects, compared to the F-86, its construction and systems were quite crude. The MiG lacked hydraulic boost for the controls, the air brakes were not large enough to do much good, it lacked any sort of radar ranging gunsight, and the double-paned structure of the canopy was prone to moisture condensation and frosting. As mentioned earlier, the range of the MiG was very short - only about 100 miles - and improved only slightly with the addition of drop tanks. MiG pilots were ordered not to fly south of Pyongyang. Surviving MiG pilots claim this was due to a policy of self restraint, similar to the American's orders not to cross the Yalu. The real reason was much simpler - the MiG simply did not have the range or endurance to fly south of Pyongyang and still make it back to their bases. Had the Communists been successful in controlling the airspace of MiG Alley and establishing functional airbases in North Korea, the MiGs would doubtless have extended their range further south.

The MiG had other performance weaknesses, as well. Robert Jackson, in his book ***Air War Korea, 1950-1953***, provides a concise summary of some of them:

> The MiG-15 was a high-level interceptor and displayed most of its aerodynamic qualities at altitudes of 20,000 feet or more. Below that, it had dangerous tendencies: on several

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> occasions UN pilots were mystified to see undamaged MiGs go into a spin during a combat manoeuvre and fail to come out of it, their pilots ejecting. Later, when a MiG-15 fell into Allied hands, thanks to the defection of a North Korean pilot, they had their answer. The cockpit of a MiG-15 featured a white line painted down the middle of the instrument panel, and if the aircraft got into a spin pilots were directed to shove the control column hard up against it. If the aircraft failed to recover after three rotations, the standard procedure was to eject. The MiG also had a number of other unpleasant shortcomings, including a tendency to oscillate - which made it a poor gun platform - and to pitch up without warning. There was no stall warning device, the cockpit pressurisation worked intermittently, and the emergency fuel pump was prone to explode when turned on, tearing off the rear fuselage. The relatively poor performance of the MiG-15 at lower altitudes usually enabled the pilots of slower F-80s and F-84s to hold their own in combat. On 24 June 1951, for example, F-80s of the 51st Wing were attacked by MiG-15s while strafing Sinanju airfield and claimed four enemy fighters damaged for no hurt to themselves. Two days later, Thunderjets of the 136th Fighter Bomber Wing, newly arrived in the theatre, destroyed one MiG-15 of a formation of six that attacked four B-29s over Yongyu airfield, and drove the rest off.[41]

It is safe to assume that most of the performance problems described above were much more pronounced among pilots with minimal training and experience. It is unlikely, for example, that MiGs flown by Russian pilots had the white line in the middle of the instrument panel or that Russian pilots relied on such simplistic, rote instructions for recovering from a spin.

Although all UN fighter-type aircraft tangled with, and scored the occasional victory over MiGs, at one point of another, the aircraft that carried the main burden of combat with the MiGs was the F-86. The remainder of this section will compare the performance of the MiG and the F-86.

One important observation of the relative abilities of the F-86 and the MiG is that in an overall sense, the F-86 was the higher quality airplane. The standard of workmanship on the F-86

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was higher, the various internal systems such as electrical and hydraulic were more effective, reliable, and sophisticated, the combat electronics of the F-86 were orders of magnitude better, and the F-86 was more reliable. The F-86 was also more maneuverable in the horizontal plane, and actually had a higher top speed. Despite all this, however, the MiG possessed a number of advantages that enabled it to dictate the terms of combat, and had the MiG been used more effectively, could easily have gained control of the air over MiG Alley.

The single biggest advantage of the MiG over the Sabre was its superior altitude capability. Combined with the immunity from attack over their own bases (Sabre pilots often spoke of their frustration at having to watch the dust trails of the MiGs taking off across the Yalu and not being able to attack the enemy while they were vulnerable) this enabled the MiGs to gain and hold altitude advantage. Since the early Sabres could not even reach the same altitude as the MiG, the MiG possessed the ability to initiate combat or decline it as they desired. They could also use that altitude advantage to make slashing diving attacks, and then use their high climb rate to elude enemy pilots. Properly used, such a tactical advantage could decimate UN aircraft, and little could have been done to counter it.

Another advantage of the MiG was its armament. The three cannon used by the MiG had been intended to shoot down large bombers, not agile fighters. Compared to the machine guns of the Sabre, they had a relatively limited amount of ammunition, a much lower rate of fire, and a relatively low muzzle velocity, although the 37 mm, in particular, had a much greater range than the Sabre's machine guns. However, the fact that both types of cannon used explosive warheads for their ammunition made any hit from them very dangerous, often deadly. The Soviets calculated that three or four hits from the lighter 23 mm cannon should destroy a Sabre, and

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usually only one hit from the larger 37 mm should do the same.

The .50 calibre guns on the Sabre, in contrast, proved to have extreme difficulty in bringing down a MiG. Both American and Soviet pilots noted the relative lack of destructive power of the Sabre's machine guns. MiG pilots felt quite safe in their aircraft, protected by an armored windscreen, a 20 mm armor plate behind the pilot, self-sealing fuel tanks, and an engine system that was very durable and damage resistant. Colonel Pepelyaev, the leading ace of the Korean War, had contempt for the armament of the Sabre:

> The American .50cal (12.7mm) guns acted on our MiGs like peas. Our aircraft would return to airfields with 40-50 bullet holes. The Americans claimed them as shot down, while our pilots were safe and sound. The MiG-15 was more survivable than the Sabre: our pilot was protected by the engine from astern, and the VK-1 or RD-45F engine itself was more survivable than the J47 on the Sabre.[42]

One problem with the MiG's armament was not the weapons themselves, but the gunsight. Unlike the radar ranging sight of the Sabre, the MiG's sight was a simple reflector one, and not a very good one at that. The MiG's sight often malfunctioned, which made it extremely difficult for the pilot to hit anything. The lower rate of fire and more limited ammunition supply of the MiG made it more difficult for an inexperienced pilot to hit his target, but in the hands of a capable pilot the MiG's armament could be devastating.

Sabre pilots were familiar with, and frustrated by, the difficulty their guns had in downing a MiG. It was not unusual for a Sabre to empty his entire ammunition load during combat with a MiG without shooting the other plane down. Problems like this reflected poor gunnery skills as well, but it is significant that during the entire war, no American pilot succeeded in downing more than two MiGs in a single sortie, despite the immense numbers of MiGs present in many air

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battles. Compared to World War II, where American pilots shot down 4, 5, or 6 enemy planes on a single mission (the record was 9, by Commander David McCampbell), this was a rather alarming development. It was this lack of destructive power of the Sabre's armament (and by extension, that of all the other Air Force fighters) that prompted Project GunVal, the attempt to replace the .50 caliber guns with rapid firing 20 mm cannon. Had the problems associated with the use of the 20 mm cannon in the Sabre been solved more quickly, there is little doubt that cannon-armed Sabres would have been more effective in combat with the MiG.

When dealing with aerial combat, another factor needs to be considered. Combat between Sabres and MiGs often took place at full throttle - close to 700 mph. This was almost twice as fast as planes engaging in aerial combat during World War II, and caused some changes to tactics. First, since the weapons used were essentially the same as in the earlier war, the ranges required for effective combat was still very close. Second, turns at the speeds used imposed near-crippling G effects even for relatively broad turns. These two factors combined to make it almost impossible for any pilot to engage in successful deflection shooting - that is, with the two planes at angles to each other. Deflection shooting has always been the most difficult of combat skills to master, and was essentially impossible under these conditions. This meant that almost all combat was done with zero deflection - from directly in front of or, more commonly, directly astern of the target. Minimal deflection shooting goes some way to compensate for poor shooting skills. Another aspect of the high-speed maneuvers that accompanied these combats was that American pilots were equipped with G-suits, and the Communist pilots were not. A G-suit is a coverall, with small pockets of liquid gel over areas especially affected by high g forces, such as the abdomen and limb joints. The liquid in the suit compresses and solidifies under high g forces, and

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helps to protect the pilot, to a limited degree, from the G forces, allowing the pilot to function under higher G loads than one without the suit.

In the area of improvements to the basic aircraft, both the MiG and Sabre were upgraded during the conflict, with the MiG-15 being replaced by the MiG-15*bis*, while the F-86A Sabre gave way to the F-86E, and in turn to various models of the F-86F. In terms of improving combat performance, the F-86 benefitted far more from these upgraded versions than the MiG did. The improved models of the Sabre finally gave it the altitude to reach the MiG and force combat, the 6-3 hard wing and flyable tail greatly improved maneuverability, so that the heavier Sabre was actually more maneuverable than the MiG, and the greater weight of the Sabre gave it superior dive performance. The kill ratio of MiGs to Sabres, always in favor of the UN pilots, increased dramatically during the last six months of the war. During May and June 1953, F-86 pilots claimed 133 MiGs destroyed for the loss of only one Sabre.[43]

Even after all the discussion of the various technical features of the Sabre vs. the MiG, one factor, the most important, remains to be considered. The great intangible of aerial combat has always been the quality, training, and motivation of the pilots involved. High levels of skill and training can compensate for and even overcome significant numerical and technological deficiencies in an air force. Likewise, even the most sophisticated and advanced fighter is not much of a threat if its pilot can barely get it off the ground, as the Luftwaffe learned in the closing days of World War II.

Perhaps the best example of pilot skill and motivation overcoming technical, numerical, and operational deficiencies can be seen in the performance of the Finnish Air Force during both the Winter War of 1940 and the Continuation War of 1941-44. In both instances, the Finnish Air

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Force, one of the world's smallest, confronted the Red Air Force, certainly the world's largest in 1940, and at least the second largest even in 1944. Although initially the Russians used second-rate equipment against the Finns in 1940, they eventually committed better equipment, and during the Continuation War the Finns faced the best aircraft the Red Air Force had. The Finns had no aircraft industry of their own, and flew only machines acquired from other nations, often older or obsolete models. The entire Finnish Air Force never numbered more than a few hundred aircraft, and yet the Finns fought the immense Red Air Force to a standstill, and even pushed them back. Finnish aces accumulated the highest scores of World War II apart from German aces, with the top Finnish ace, Warrant Officer Ilmari Juutilainen, scoring 94 confirmed kills. Even more amazing was the fact that he scored 34 of those kills while flying the Brewster Buffalo, an aircraft considered obsolete and unfit for combat by the US Navy, which had initially ordered it.[44]

This example shows how crucial pilot skill, training, experience, and aggression is to success in air warfare. It is in this realm that the United States possessed the greatest advantage over their Communist opponents in Korea. To better understand the crucial advantage possessed by the American fliers, the disposition and policies of each side will be examined in turn.

Once the MiG was encountered, the United States Air Force quickly sent two fighter groups equipped with the very latest jet fighters to Korea. The 49th Fighter Bomber Wing, equipped with F-84Es, was quickly deduced to be no match for the MiG, especially at high altitude, and usually relegated to ground attack duties, although they occasionally performed bomber escort as well. The 4th Fighter Interceptor Wing, with F-86As, was expected to carry the burden of combat with the MiG. Many of the pilots in the 4th were veterans of World War II, some of them aces. All of them were highly trained, with a great deal of time flying the F-86, and

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were eager to come to grips with the enemy.

Later, when the threat of the MiGs increased, the 51st Fighter Interceptor Wing was converted from F-80Cs to F-86Es, with small numbers of the F-86Es also going to the 4th FIW. The 51st was composed of seasoned combat veterans, having been active in combat since the first days of American air activity in Korea. Eventually the 8th Fighter Bomber Wing also converted from F-80Cs to F-86Fs, although the majority of their missions were ground attack and not air superiority. Again, the 8th was a veteran combat unit, with a great deal of experience in battle in Korea.

American policy with regard to combat units, including air units, was to leave the unit in place, and feed replacements to it at regular intervals to keep it up to strength. While for ground units this policy often resulted in a degrading of combat effectiveness over an extended time, for air units this was a sensible policy. Aircrew in Korea were required to serve what was known as a 'tour of duty.' This was a set amount of time the individuals had to serve in combat before they were rotated to a non-combat posting. Although there was some debate about the exact definition of a tour of duty at the beginning of the war, it was eventually determined that 100 combat missions would be the standard tour. This meant that fighter squadrons saw a small but regular turnover of their pilots, as new ones arrived to replace those who had finished their tour.

This system meant that the small number of new pilots could be easily accommodated by the unit without degrading combat effectiveness. The new pilots, in turn, could absorb the deadly lessons of combat from experienced pilots in a relatively safe environment, flying easier missions until they were deemed ready for the test of combat. This meant that despite what amounted to a complete turnover of personnel several times over during the war, the 4th FIW never suffered a

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serious decline in combat effectiveness. The other F-86 units, despite shorter periods operating with the type, had similar experiences.

The tour system was not perfect. Many of the replacement pilots who came to the 4th in 1952 were not very excited to be in combat. Most of them were members of the reserves, who had been involuntarily activated and shipped off to Korea. They were often not quite as aggressive as the earlier pilots had been, and were content to simply finish out their tour and go back home. They were still highly competent pilots, however, and the unit as a whole was not harmed by their presence. Also, 1952 saw the first of the new generation of fighter pilots, the ones fresh from advanced training, cocky and eager to prove themselves. A number of these younger pilots went on to become aces as well. These young pilots also found it much easier to adapt to the newer features of the Sabre, such as the radar ranging gunsight. Some pilots also requested a second tour of duty in Korea. Since these pilots were usually among the most skilled and aggressive, with perhaps a touch of "MiG Fever", they were welcome as well. James Jabara, the second highest scoring American ace of the war, was one of these pilots. He split his scoring almost exactly between the two tours, scoring seven kills his first tour and eight the second.

Not only were American pilots highly skilled, they used effective and proven air tactics. The basic tactical formation of the Sabres was the two plane element, and the two element flight. This was the same 'finger four' formation used so successfully in World War II. American tactics and formations were designed for a combination of flexibility, mutual protection, and aggression. In a sense, American tactics and formations acted as 'force multipliers', giving the American pilots the ability to disrupt and even shatter the larger, more rigid MiG formations with only a few planes.

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As a result of the policies of the American government and the Air Force, there were never a large number of Sabres in Korea. Each of the three F-86 groups present at the end of the war, the 4th FIW, the 51st FIW, and the 8th FBW, had an authorized strength of about 75 aircraft, for a combined (paper) strength of approximately 225 aircraft. For most of the first year of Sabre/MiG combat, only the 4th, with about 75 aircraft, many of them inoperable due to maintenance difficulties, contested the Soviets. Despite these difficulties, most American pilots never hesitated to take the fight to their enemies. The quote which opened this chapter is typical of the attitude of so many American pilots, and goes a long way towards explaining their ability to hold off larger numbers of enemy aircraft that were, in some respects, superior to their own.

The Communist direction of their portion of the air war over Korea reveals a different approach to the conflict, as well as some rather serious errors and poor decisions. These factors help explain the inability of the Communist air forces to achieve air superiority over Korea, and the general inability of the quite sophisticated and effective MiG-15 to exert a decisive influence on the air war, especially given the large number of them in combat operations.

The MiGs encountered by UN air forces in Korea came from a variety of sources. The first was the "loaning" of entire Soviet fighter units to the Chinese Air Force. A Soviet fighter corps was sent as the logistical and administrative controller for these units, and then individual fighter regiments and divisions were transferred in. The Soviet fighter regiment was the standard operational combat unit, equivalent to an American fighter squadron. The Fighter division was roughly equivalent to the American group, and the fighter corps was equivalent to an American administrative unit, such as an air force.

The Soviet pilots who served in China were all "volunteers" and were, for the duration of

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their tour, officially members of the Chinese Air Force. They wore Chinese clothing and uniforms, and were given all sorts of dire warnings about not revealing their origins if they were captured by the Americans. Some of the early Soviet fighter regiments that served in China were commanded by veterans of what the Soviets called "The Great Patriotic War." They were generally well trained, and often highly motivated. Convinced that they were helping to resist "capitalist aggression," and shown bomb devastated North Korean communities as evidence, these Russian air units were prepared to fight hard.

The level of preparation of the units sent to fight in Korea varied considerably. When Colonel Pepelyaev learned that the 196th Fighter Air Regiment, which he commanded, would be sent into combat, he immediately instituted a rigorous training program. Pepelyaev had seen combat during World War II, and wanted his pilots to be as well prepared as possible. His unit performed well, learning the lessons of combat quickly, and developing more effective tactics that enabled them to more than hold their own in combat. Pepelyaev was credited with 23 aerial victories during his relatively short service in Korea (April 1951 to January 1952). He was awarded the Hero of the Soviet Union for his efforts.[45]

Unfortunately, Pepelyaev and his pilots were unable to pass on the lessons they had learned. When his unit was rotated out of Korea, it had only a few days of contact with the new unit that was replacing it. This was not nearly near enough time to acquaint the newcomers with the reality of combat, and the new unit was not as well trained to begin with.

> The Soviets rotated whole units out of combat at once. Rotating air units (rather than individuals) through the Korean conflict had an inherent flaw. New pilots went into combat without experienced colleagues beside them. Newcomers "stepped on the same rake" (from a Russian joke about repeatedly making the same

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> mistakes). Pilots who completed a tour of duty could pass their experience only orally to newcomers. There was a decline in MiG activity after each turnaround of pilots, and one consequence was increased losses. The Americans, in contrast, rotated individuals, not squadrons. "Elders" coached newcomers as they gained experience. This rotation scheme typifies the way Soviet leaders, military and civil, approached any activity. If something did not succeed, shallow decisions, often not touching on the cause of the problem, were usually taken. If F-86s won a battle with MiG-15s, Soviet pilots and commanders were blamed and then replaced.[46]

This rotation policy was decided on at the highest levels of the Soviet government. The apparent rationale for such a decision was the desire to give as many units as possible some combat experience. The fact that this policy led to increased losses and poor combat performance was evidently not relevant at all to the decision. The resulting inability to capitalize on the MiG's performance to gain control of the airspace over North Korea mattered not at all to those making the decisions. Even the Soviet general commanding all Soviet air operations in Korea could not alter the situation. Lieutenant General Georgy Lobov, commanding the 64th Fighter Air Corps (roughly equivalent to the American 5th Air Force), had this to say about the situation:

> People were replaced in the 64th FAC by relieving an entire division at a time. Arriving replacements had only a vague idea of combat tactics. This caused newly arrived units to lose many rookie pilots. Besides, participation by the VVS in this war was secret and was concealed from our own citizens (though it was not a secret from the rest of the world). Experience was gained at the expense of our pilot's lives was studied by VVS and by PVO officers, but was kept strictly confidential.
>
> In addition, in many air units flight safety, rather than battle training enjoyed high priority. Air commanders of all ranks were forced to simplify training. For example, training flights were made in close formations, and, as a rule, with external tanks that limited maneuverability. Mock air battles during training were waged against targets that were not maneuvering or mounting any opposition. We addressed higher authorities criticizing this faulty system of training and replacing pilots. But all remained as it was.

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> It was simpler to move entire divisions at the stroke of a pen, rather than to train every regiment, every pilot, for coming battles. [47]

This rotation policy led to a pattern that became familiar to American pilots. The MiGs would be tentative and reluctant in combat, with perhaps a few aircraft engaging, and others remaining out of the action. Then, over time, the tactics and confidence of the MiGs would improve, and larger fights (called "furballs" by American pilots) would take place. The MiGs would become more dangerous, and American losses would rise. Then abruptly the pattern would repeat itself.

Although the Soviet combat units were present in Korea until almost the endof the war, there were never a great many of them at one time. General Lobov estimated his command at approximately the same size as the combined forces of the 4th and 51st groups, about 200 machines. However, the Soviets were not the only ones flying MiGs over northern Korea. Beginning in 1952, Chinese pilots began to operate MiGs as well. The Chinese forces quickly expanded in size, comprising the majority of the estimated 1,000 MiGs available by 1953.

The large number of Chinese MiG pilots was a deceptive statistic. Many of these pilots, often weak and severely malnourished, could barely manage to fly the airplane, and were hardly capable of successful combat operations with the highly trained Americans. These Chinese pilots had been trained in extreme haste, and largely by rote memorization. A handful of skilled and aggressive Russian instructors served with Chinese units. These were the "honchos" noted by American pilots later in the war, who would do most of the fighting, while the majority of the Chinese pilots remained unable to engage the Americans successfully.

Chinese pilots could be, on occasion, quite aggressive, sometimes achieving results through sheer numbers. But even the least trained of the Soviet units had little but contempt for

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the flying skills of the Chinese, or their wildly exaggerated claims of victories after an engagement. The North Korean pilots which began flying the MiG in the closing months of the war were, if anything, even more poorly prepared than the Chinese. During that period American pilots described encounters with enemy MiGs that took no evasive action at all, even after being fired on, but continued to fly straight and level. The American pilots would continue to shred the MiG, with the enemy pilot apparently simply hunched behind his armor plate in the cockpit. When his plane was finally too shot up, the MiG pilot would simply eject. This complete lack of anything even remotely resembling combat skills was a major factor in the huge number of MiGs downed in the final few months of the war, for almost no Sabre losses.

After the war, the United States claimed a kill ratio of 14 to 1 for its Sabres in Korea. That is, fourteen enemy planes (MiGs) were claimed destroyed for every Sabre lost in combat. These figures have come under scrutiny more recently, and they have been adjusted downwards several times. The admitted loss of Sabres in Korea has gone up several times, and the number of verified enemy kills has declined considerably. Still, even with considerably revised figures, the Sabre pilots managed to attain at least a 3 to 1 kill ratio. Not a bad accomplishment against an opponent who severely outnumbered them, and for much of the time, could, by use of superior altitude capability, dictate the terms of the battle. Whether the Sabre or the MiG was the superior fighter is a question that began to be debated even before the shooting stopped. The reality seems to be that the two planes were quite evenly matched, and that the outcome hinged far more on pilot skill and training, and the circumstances of battle, than the aircraft itself.

There is no question, however, of the skill, training, and determination of the American pilots who flew jet fighters into aerial combat in Korea. Their courage maintained, by a narrow

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margin, air superiority for UN forces, and allowed UN ground forces to fight without hindrance from enemy airpower and with the support of American aerial firepower. And in the F-86 Sabre, American pilots had a world-class fighter airplane, which could hold its own against the best the Communists could throw at it.

American Air Force jet fighters had their baptism of fire in Korea. Sent to a distant, harsh, and poorly developed land, hampered by shortages of all kinds, they waged war against an enemy who was frighteningly numerous, zealously aggressive, and who possessed modern and effective equipment. Fighting in a place, at a time, and against an opponent none of their designers could have envisioned, American jet fighters proved to be tough and effective combat machines. They performed every mission asked of them, including some they had never been intended for.

One reason for the excellent performance of the American jet fighters in such a difficult environment as Korea is what might be called the unofficial philosophy of all American aircraft companies - "Build 'em tough." This philosophy has its origins in the 1930s, in the early days of metal construction for aircraft. Some American companies have taken this concept to even greater lengths, with the Grumman Corporation, for example, building such strong airplanes that the company became known as the "Grumman Ironworks." This toughness had its origins at least in part in the sheer size and geographic diversity of the United States. Brigadier General Ben Kelsy, chief of the USAAF Fighter Project from 1934 to 1943 had this to say about American aircraft:

> Peacetime maneuvers for the United States involved deployment from Michigan to Florida, from one coast to the other, from arctic climate to deserts, and from sea level to the high plains and mountain areas. Sequential planes coming from a factory might be assigned to Alaska, or Panama, Florida, or Arizona. When

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> gathered for maneuvers, they might mass in Louisiana or New England in the winter. Cold weather testing was done on new articles in Fairbanks, but gunnery contests might be held on Muroc Dry Lake or Honey Lake north of Reno. The plane automatically included provisions for operating in any or all of these surroundings. That versatility was unique in this country.[48]

American jet fighters in Korea, despite operating in a harsh climate with minimal support facilities, proved to be reliable and tough, trusted by their pilots to perform their missions and bring them home again.

In a way, the timing of the Korean War was fortuitous for the Air Force's jet fighters. Had the war happened a few years earlier, many of the later first generation fighters would still have been undergoing testing or working the bugs out in their early career. The combat zone in Korea would hardly have been the place to attempt to diagnose and fix the problem of the catastrophic wing failures or the bomb buffeting problems of the early F-84s, for example. Had the war occurred a few years later, the first generation planes would largely have been obsolete and replaced by the early examples of the second generation of jet fighters, which had their own developmental problems, often severe ones. Because the Korean War happened when it did, the United States Air Force had a number of well developed and reliable jet fighters with which to fight.

The Korean War proved that the first generation of American jet fighters were tough, capable combat machines. The lessons learned in that conflict helped to shape successive generations of fighter planes. The Korean War can be accurately labeled the first jet war, and in it jet fighters proved that they were, indeed, the weapon of the future.

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1. Dorr ***F-86 Sabre***, p. 133.

2. Stanley Sandler ***The Korean War: No Victors, No Vanquished*** The University Press of Kentucky, 1999, p. 137.

3. Ibid., p. 5.

4. ***Department of Defense Almanac*** Washington, DC:Department of Defense Publications, 1993, p. 47.

5. Ibid., pp. 1-16.

6. The number of works devoted to the air war in Korea is quite small. The first, and by far the most detailed is Robert F. Futrell's ***The United States Air Force in Korea: 1950-1953***. First published in 1961, it has been revised and republished in 1983 and 1991. Exhaustively detailed, it is the official Air Force history of the conflict, and therefore tends to portray the Air Force in a generally favorable light. More recent works include Robert Jackson's ***Air War Korea: 1950-1953***, and Robert F. Dorr and Warren Thompson's ***The Korean Air War***. Both these books, although much shorter than Futrell's book, include all elements of the UN air war, including the US Navy and Marine Corps and allied units, such as the South African and ROK units. A recent book which focuses on the bombardment strategies of the Air Force is Conrad Crane's ***American Airpower Strategy in Korea: 1950-1953***. A couple of books which begin to present at least the Russian perspective on the air war are ***Korean War Aces*** by Robert F. Dorr, Jon Lake and Warren Thompson, which includes a chapter on Russian aces, and ***MiG-15: Design, Development, and Korean War Combat History*** by Yefim Gordon and Vladimir Rigmant. This book not only includes a chapter on the combat history of the Russian MiGs, but also some fascinating reminiscences by various Soviet pilots from the conflict. Also, various histories of specific aircraft, especially the F-86, usually include sections on the combat experience in Korea.

7. The total number of Stormoviks produced was 36,163. Hans-Heiri Stapfer ***Il-2 Stormovik in Action*** Carrollton TX: Squadron/Signal Publications, 1995, p. 5.

8. Robert Jackson ***Air War Korea: 1950-1953***, Shrewsbury, England: Airlife Publishing, 1998, pp. 9-10.

9. Ibid., pp. 11-4.

10. Ibid., p. 25.

11. Conrad Crane ***American Airpower Strategy in Korea: 1950-1953*** The University Press of Kansas, 2000, pp. 40-55.

12. The first combat encounters with the MiG-15 came on 1 November 1950, when F-51D Mustangs were attacked by six MiGs, although no losses were sustained by either side. History's first jet vs. jet combat took place on 8 November 1950, when First Lieutenant Russell J. Brown,

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flying an F-80C, *Elene*, managed, with only one of his six machine guns functional, to shoot down one of half a dozen MiGs that he and his wingman had attacked. Lt. Brown gets credit for the first jet vs. jet combat victory in history. The next day, 10 November 1950, Lietuenant Commander William Thomas Amen, flying an F9F-2 Panther also shot down a MiG. Robert F. Dorr, Jon Lake and Warren Thompson ***Korean War Aces*** London: Osprey Publishing, 1994, pp. 15-6.

13. Robert F. Futrell ***The United States Air Force in Korea: 1950-1953*** Washington DC: Office of Air Force History, 1991, pp. 199-238.

14. Ibid., pp. 239-284.

15. Ibid., pp. 285-312.

16. Jackson ***Air War Korea***, pp. 95-100.

17. Ibid.

18. Dorr, Lake, and Thompson ***Korean War Aces,*** pp. 27-8.

19. Jackson ***Air War Korea***, pp. 85-8, 107-110.

20. Dorr, Lake and Thompson ***Korean War Aces***, pp. 32-3.

21. Jackson ***Air War Korea***, pp. 99-106.

22. Dorr, Lake and Thompson ***Korean War Aces***, p. 41.

23. Crane ***Airpower Strategy in Korea***, pp. 155-70.

24. Futrell ***United States Air Force in Korea***, pp. 688-93.

25. Crane ***Airpower Strategy in Korea***, pp. 171-84.

26. Futrell ***United States Air Force in Korea***, pp. 62-6.

27. Crane ***Airpower Strategy in Korea***, pp. 1-9.

28. Futrell ***United States Air Force in Korea***, pp. 59-60.

29. Hughes and Dranem ***Sabrejet Day Fighters***, pp. 29-30.

30. Jackson ***Air War Korea***, pp. 77-8.

31. Ibid., p. 98.

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32. Ibid., p. 198, Futrell ***United States Air Force in Korea***, p. 690.

33. Crane ***Airpower Strategy in Korea***, pp. 29-30.

34. Yefim Gordon and Vladimir Rigmant ***MiG-15: Design, Development, and Korean War Combat History*** Osceola, WI: Motorbooks International, 1993, p. 8.

35. Ibid., pp. 5-19.

36. William Green and Gordon Swanborough ***The Complete Book of Fighters: An Illustrated Encyclopedia of Every Fighter Aircraft Built and Flown*** London: Salamander Books, 1994, pp. 391-2, 449-52.

37. Gordon and Rigmant ***MiG-15***, pp. 38-42.

38. Ibid., pp. 110-19.

39. Ibid., p. 112; Hugh Morgan ***Soviet Aces of World War 2***, London: Osprey Books, 1997, p. 72.

40. Dorr, Lake and Thompson ***Korean War*** Aces, pp. 81-9.

41. Jackson ***Korean Air War***, pp. 82-3.

42. Gordon and Rigmant ***MiG-15***, p. 136.

43. Jackson ***Air War Korea***, pp. 137-46.

44. Kari Stenman and Kalevi Keskinen ***Finnish Aces of World War 2*** London: Osprey Books, 1998, p. 84.

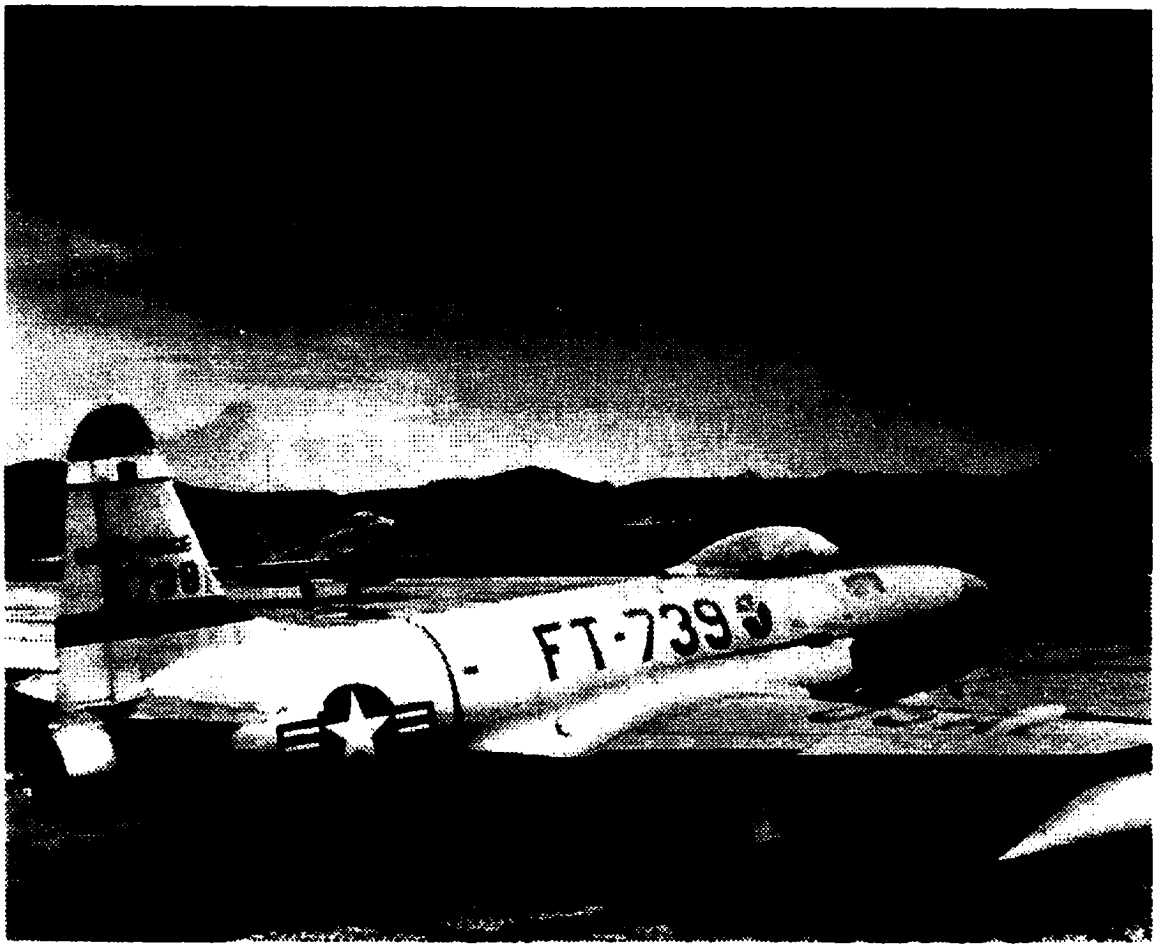
45. Gordon and Rigmant ***MiG-15***, pp. 134-9.

46. Ibid., p. 112.

47. Ibid., pp. 120-1.

48. Eric M. Bergerud ***Fire in the Sky: The Air War in the South Pacific*** Boulder, CO: Westview Press, 2000, p.231.

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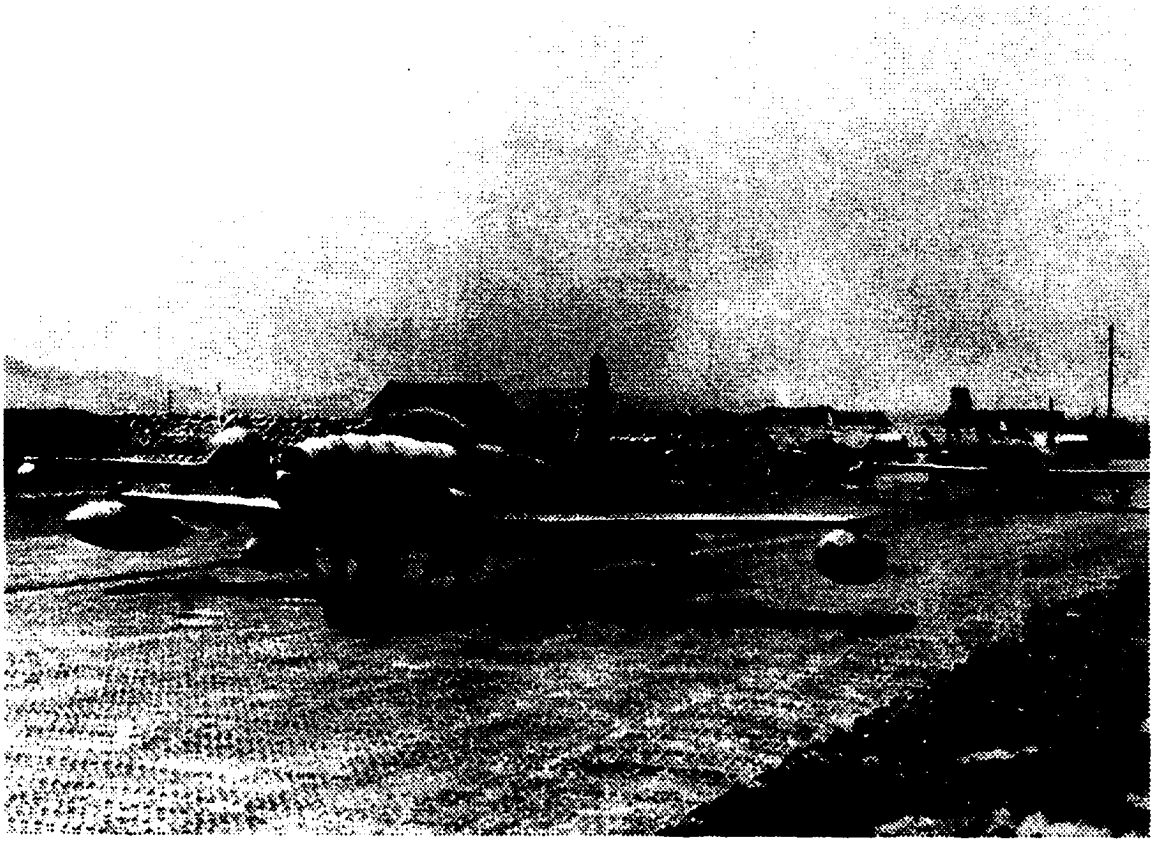
A pair of 4th Fighter Interceptor Wing F-86As take off, while a bombed-up 51st Fighter Interceptor Wing F-80 waits for JATO rockets. Photo credited to FEAF, dated 27 August 1951. (National Archives, Photographic Division, Box 3003, Number 26141)

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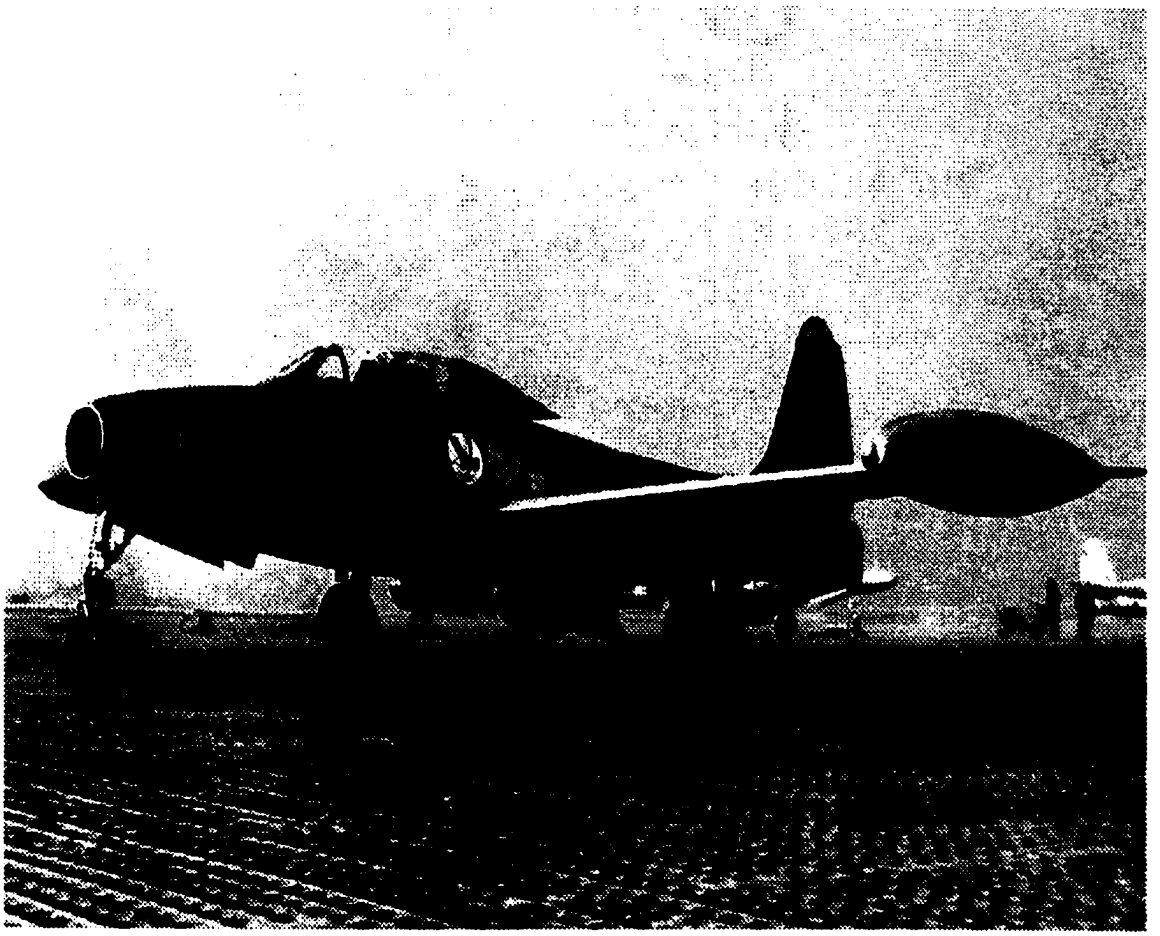
An F-80C of the 49th Fighter Bomber Wing sits forlornly in the water after a storm. This photo gives some idea of the primitive conditions at the Korean airbases. Note the larger Misawa tanks on the wingtip. Photo credited to FEAF, dated 21 September 1951. (National Archives, Photographic Division, Box 3003, Number 26142)

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Bombed-up F-80Cs taxi out for another mission. The larger Misawa tanks can be seen on the wingtips. Note the Marston Mat covering the taxiway. The sandbags protecting the base structures in the background are a protective measure taken because of "Bed Check Charlie". Photo credited to FEAF, dated 5 May 1952. (National Archives, Photographic Division, Box 3003, Number 26158)

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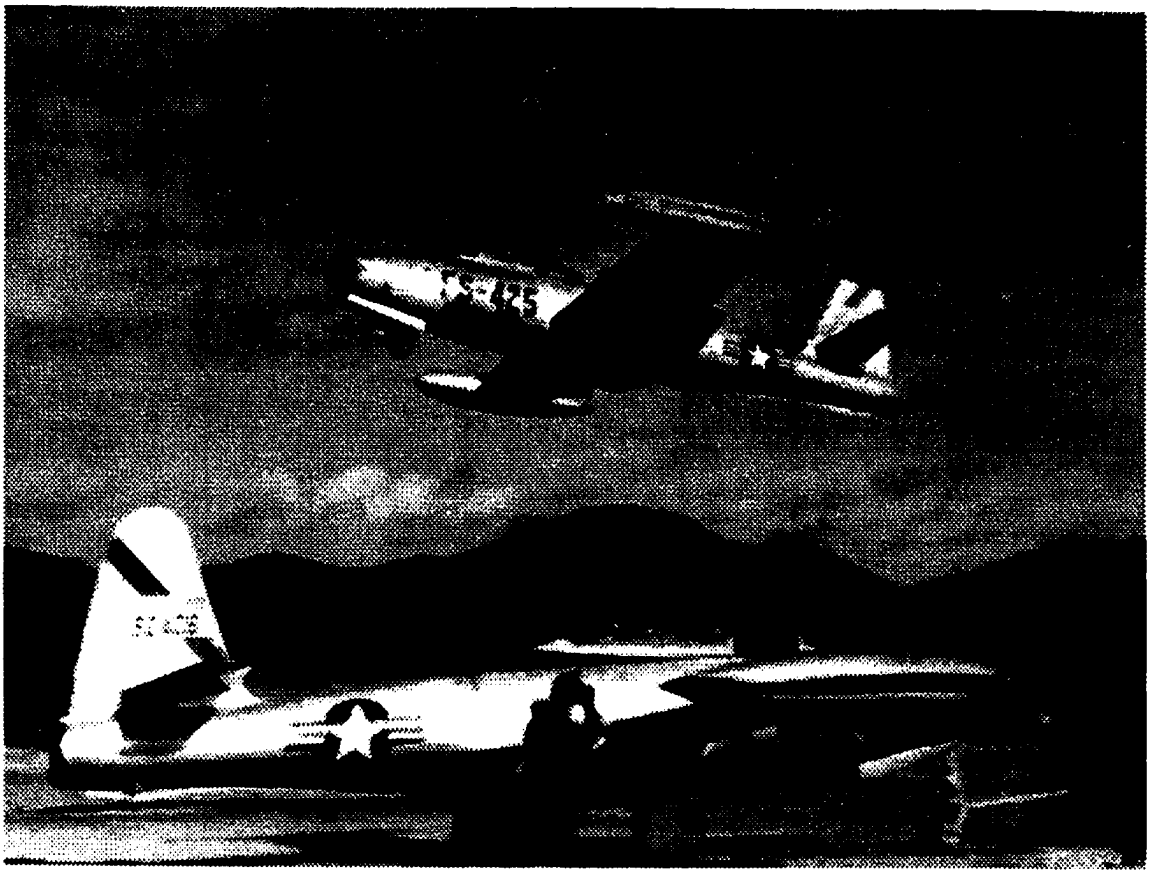
"1,000 hours for F-84, Miss Jacque II" This F-84G, belonging to the 136 Fighter Bomber Wing, is the first Korean combat plane to accumulate 1,000 hours of combat flight time. This milestone was accomplished on the plane's 364th mission, during Operation Strangle. Photo credited to FEAF, dated 11 March 1952. (National Archives, Photographic Division, Box 3003, Number 26231)

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A rocket-armed F-80C takes off on another mission. The length of the Misawa tanks can be clearly seen in this view. Photo credited to FEAF, dated 19 December 1950. (National Archives, Photographic Division, Box 3003, Number 26432)

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A rocket-armed F-84E of the 27th Fighter Escort Wing climbs into the air, while its sister ship is towed either to or from a take off. Photo dated 22 January 1951. (National Archives, Photographic Division, Box 3003, Number 26489)

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An F-80 displaying damage taken while on a strafing run in Korea. According to the original caption, this damage was not caused by anti-aircraft fire but by the pilot colliding with the tops of some trees. This amply illustrates the hazards of low flying ground attack missions, quite apart from the dangers of combat. The pilot retained control of the plane and made a safe landing. Photo dated 12 September 1951. (National Archives, Photographic Division, Box 3001, Number 25872)

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1st Lieutenant Merwin R. Read, jr., of the 49th Fighter Bomber Wing, surveys the damage to his F-84 caused by what was estimated to be a 37 mm anti-aircraft round. The round missed the landing gear by inches, and punctured a fuel cell. Although fuel was lost, the self-sealing tank held, and there was no fire. Lt. Read made a safe landing. Photo credited to FEAF, dated 15 September 1952. (National Archives, Photographic Division, Box 3001, Number 25903)

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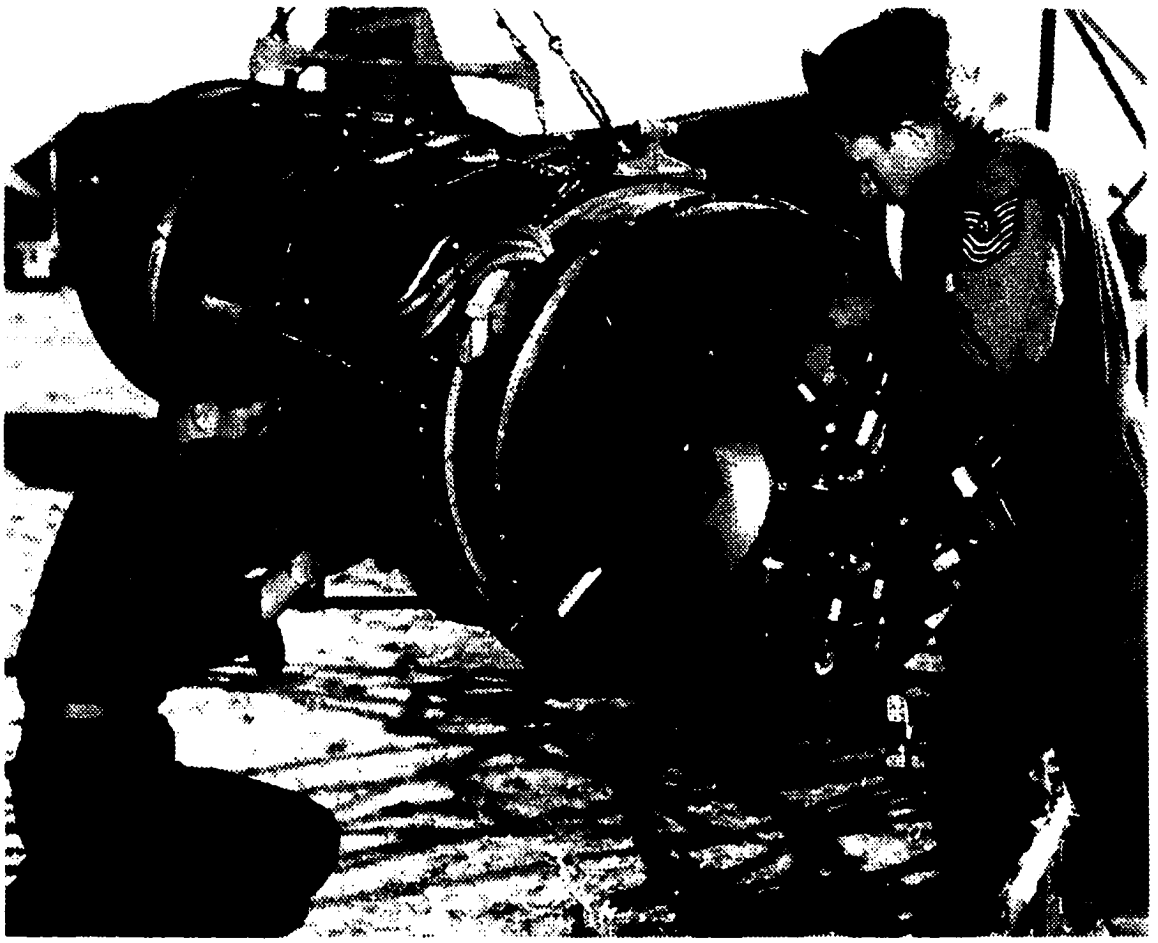
Lieutenant William S. O'Leary of the 8th Fighter Bomber Wing gazes at the flak damage to his F-86F Sabre. Lt. O'Leary's plane was hit during the pull-out from a dive bombing attack, but he was able to make a safe landing despite having a good piece of his vertical stabilizer shot away. Photo credited to FEAF, dated 16 June 1953. (National Archives, Photographic Division, Box 3001, Number 25908)

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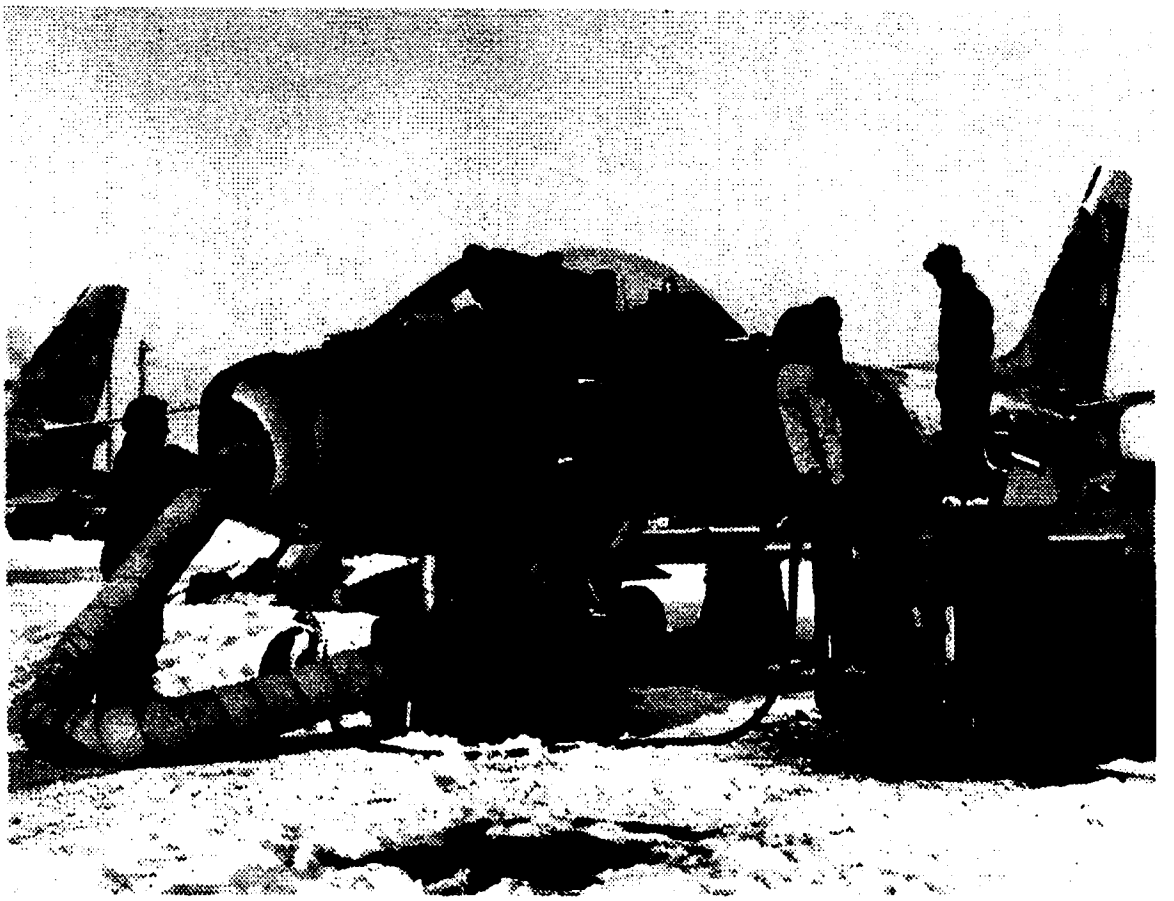
The J33-A-35 engine of an F-80C has been removed for maintenance. The men performing the work are, from left to right, Staff Sergeant J. C. Brock, Master Sergeant J. R. Jerden, and Technical Sergeant H. W. Everhart. Photo dated 21 August 1950. (National Archives, Photographic Division, Box 3034, Number 33149)

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The J35-A-17 engine from an F-84E is undergoing a 50 hour inspection by Corporal Paul B. Councelman and Master Sergeant Robert L. Brown. Note the slimmer outline of the axial flow J35 compared to the bulkier centrifugal flow J33 from the F-80. Photo credited to FEAF, dated 2 January 1951. (National Archives, Photographic Division, Box 3034, Number 33181)

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A cold weather start is being performed on an F-86F of the 51st Fighter Interceptor Wing. Air heated to 300 degrees Fahrenheit is pumped into the engine intake to thaw out the various lubricants in the engine. Once again the harsh environment of the Korean battlefield is well illustrated. Photo credited to FEAF, dated 27 January 1953. (National Archives, Photographic Division, Box 3034, Number 33202)

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Staff Sergeant Robert V. Sanders brushes a night's snow accumulation off an F-80C belonging to the 8th Fighter Bomber Wing. The long line stretching down at a diagonal from just below his broom is a tie-down strap for a special canvas tarpaulin used to cover the cockpit. Photo credited to FEAF, dated 22 January 1952. (National Archives, Photographic Division, Box 3035, Number 33303)

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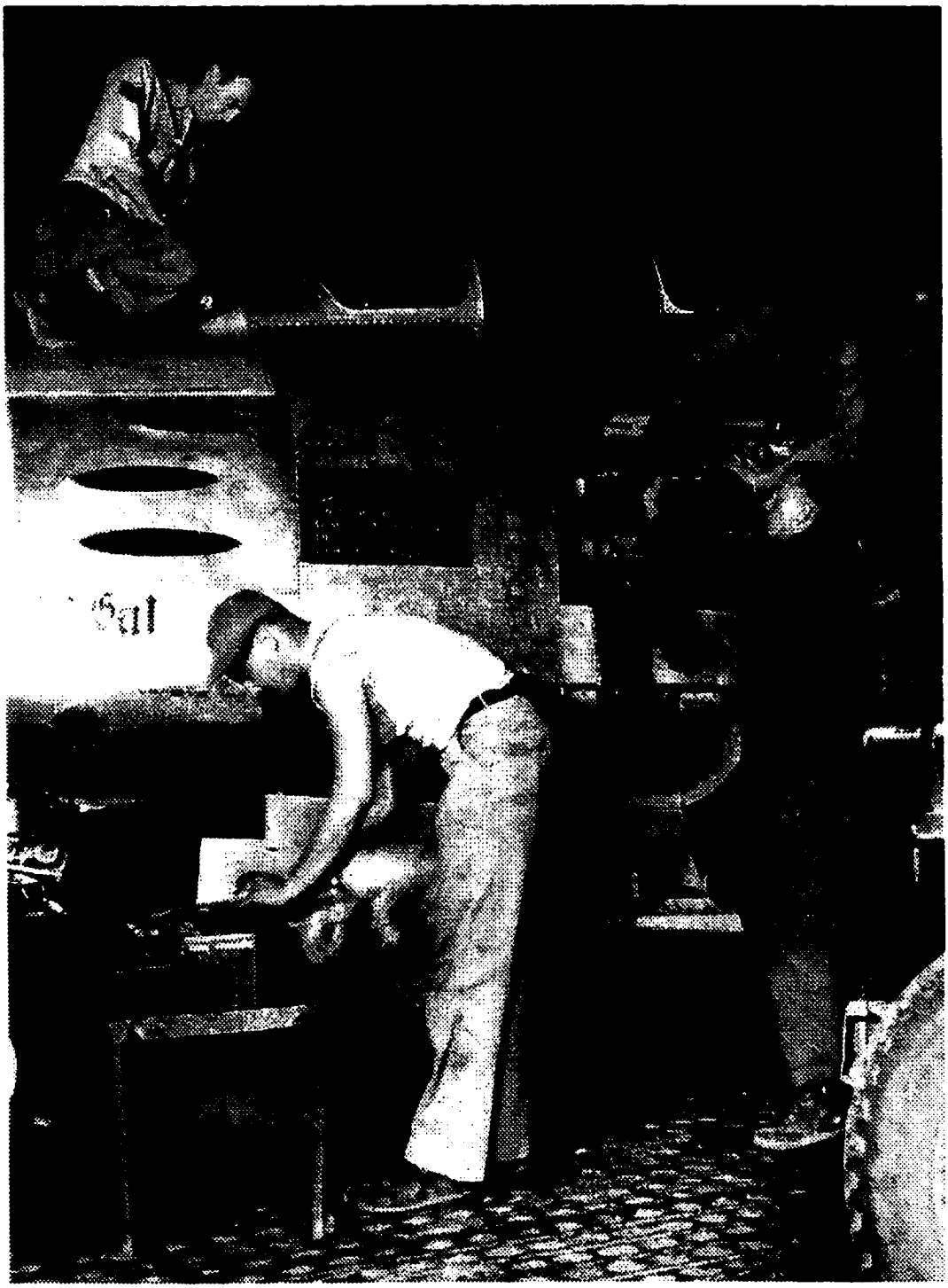
Private First Class Elwood Olinger works on the J33 engine of an F-80C, while it is still attached to the aircraft. Note how the removable tail section makes access to the engine easy and direct. Photo credited to FEAF, dated 17 July 1950. (National Archives, Photographic Division, Box 3035, Number 33343)

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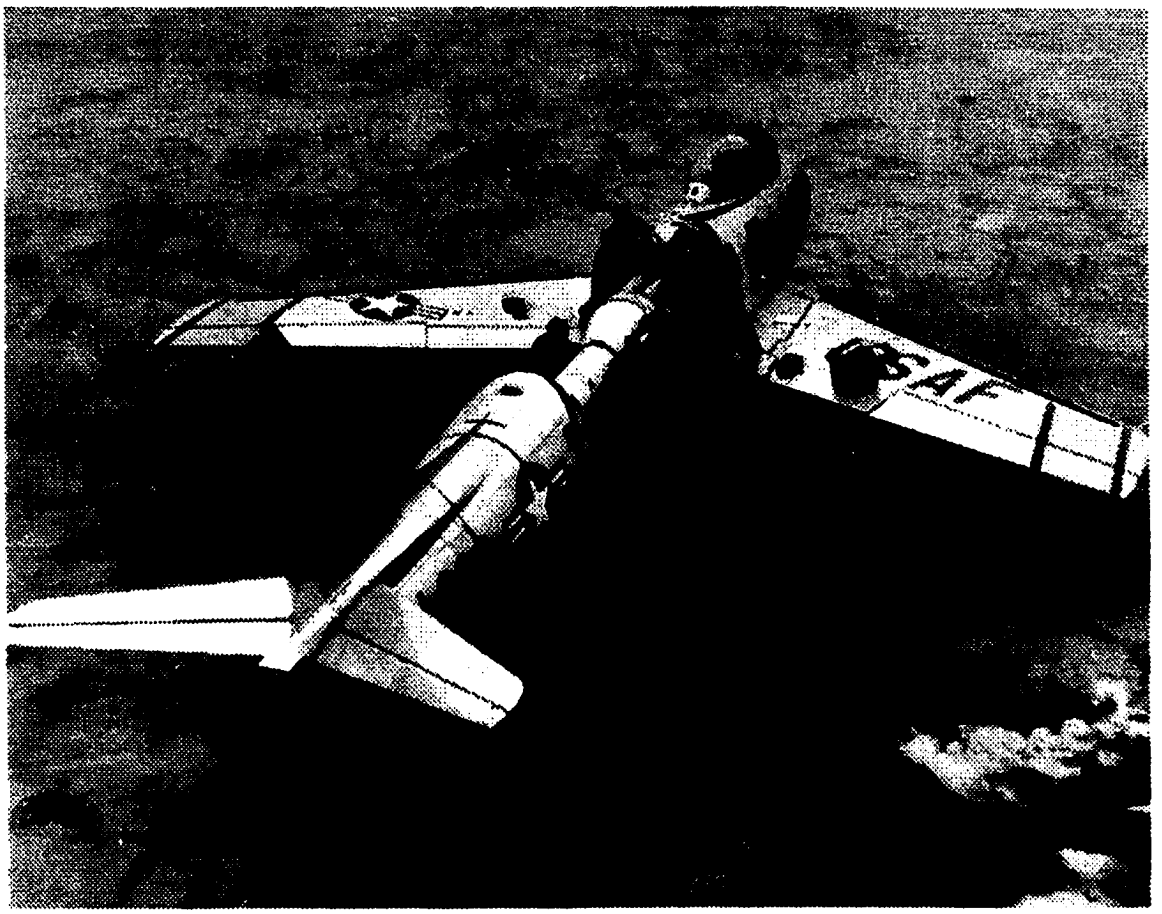
An F-86 testing its guns at night. The testing of machine guns, with the use of (illuminated) tracer rounds was often done at night. The tests were to determine if the guns were properly aligned and concentrated. Misaligned guns could seriously diminish the firepower of a fighter. Photo credited to FEAF, dated 2 May 1952. (National Archives, Photographic Division, Box 3035, Number 33425)

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Armorers loading the .50 caliber machine guns of an F-86 belonging to the 4th Fighter Interceptor Wing. Photo credited to FEAF, dated 24 June 1952. (National Archives, Photographic Division, Box 3035, Number 33438)

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An F-86F of the 4th Fighter Interceptor Wing with the tail section removed for access to the engine. This F does not yet have the 6-3 hard wing. Photo credited to FEAF, dated 23 April 1953. (National Archives, Photographic Division, Box 3035, Number 33440)

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Serial Numbers

Bell P-59 Airacomet

Model	Serial Numbers	Total
XP-59A	42-108784 / 42-108786	3
YP-59A	42-108771 / 42-108783	13
Total P-59 prototypes		16
P-59A-1	44-22609 / 44-22628	20
P-59B-1	44-22629 / 44-22658	30
Total of all P-59 machines		66

Lockheed P-80 Shooting Star

Model	Serial Numbers	Total
XP-80 "Lulu-Belle"	44-83020	1
XP-80A "Gray Ghost"	44-83021	1
XP-80A "Silver Ghost"	44-83022	1
YP-80A	44-83023, 44-83025 / 44-83035	12
XF-14	44-83024	1
Total P-80 prototypes		16
P-80A-1	44-84992 / 44-85199	208
P-80A-1	44-85202 / 44-85336	135
P-80A-5	44-85337 / 44-85491	155
P-80A-5	45-8301 / 45-8363	63
XP-80B (P-80R)	44-85200	1
XFP-80A	44-85201	1
FP-80A-5	45-8364 / 45-8477	114
Total P-80A models		677
P-80B-1	45-8478 / 45-8565	88
P-80B-1	45-8596 / 45-8717	122
P-80B-5	45-8566 /45-8595	30

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Total P-80B models		240
Model	**Serial Numbers**	**Total**
P-80C-1	47-171 / 47-224	54
P-80C-1	47-525	1
P-80C-1	47-600 / 47-604	5
P-80C-1	47-1380 / 47-1411	32
P-80C-1	48-376 / 48-396	21
P-80C-1	48-863 / 48-912	50
P-80C-5	47-526 / 47-600	75
P-80C-10	49-422 / 49-878	457
P-80C-10	49-1800 / 49-1899	100
P-80C-10	49-3597 / 49-3600	4
TP-80C	48-356 / 48-375	20
TP-80C	48-913 / 48-920	8
TP-80C	49-879 / 49-1006	128
Total P-80C models		955
Total of all P-80 machines		1,888

Republic F-84 Thunderjet

Model	**Serial Numbers**	**Total**
XP-84	45-59475 / 45-59477	3
YP-84A	45-59482 / 45-59496	15
Total P-84 prototypes		18
P-84B	45-59497 / 45-59581	85
P-84B	46-533 / 46-673	141
XP-91	46-680 / 46-681	2
Total P-84B models		228
P-84C	47-1412 / 47-1602	191
F-84D	48-641 / 48-794	154
F-84E	49-2022 / 49-2429	408
F-84E	50-1111 / 50-1230	120

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F-84E	50-1813 / 50-1837	25
F-84E	51-577 / 51-691	215
F-84E	51-9548 / 51-9622	75
YF-84F	49-2430	1
Total F-84E models		844

Model	Serial Numbers	Total
F-84F	51-1346 / 51-1707	362
F-84F	51-1710 / 51-1827	119
F-84F	51-17061 / 51-17088	28
F-84F	52-6355 / 52-7288	874
F-84F	52-10510 / 52-10528	29
F-84F	53-6532 / 53-7230	699
F-84F-GK	51-9311 / 51-9547	237
F-84F-GK	52-8767 / 52-9128	362
RF-84F	51-1829 / 51-1958	130
RF-84F	51-11250 / 51-11297	48
RF-84F	51-16996 / 51-17058	63
RF-84F	52-7229 / 52-7475	247
RF-84F	52-8717 / 52-8766	50
RF-84F	53-7521 / 53-7697	177
RF-84F	57-6552 / 6716	165
RF-84K (FICON)	52-7254, 52-7278	2
YF-84J	51-1708 / 51-1709	2
YRF-84F	51-1828	1
YF-84H	51-17059 / 51-17060	2
Total F-84F models		3,597
F-84G	51-692 / 51-766	75
F-84G	51-767 / 51-1343	577
F-84G	51-9623 / 51-11249	1,627
F-84G	51-11643 / 51-16751	109
F-84G	52-2893 / 52-3329	437
F-84G	52-8287 / 52-8466	200
YF-84F	51-1344 / 51-1345	2
Total F-84G models		3,027
Total of all F-84 machines		8,059

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North American F-86 Sabre

Model	Serial Numbers	Total
XP-86	45-59597 / 45-59599	3
F-86A-1	47-0605 / 47-0637	33
F-86A-5 (orig. F-86B)	48-0129 / 48-0316	186
F-86A-5	49-1007 / 49-1068	62
F-86A-5	49-1070 / 49-1339	270
F-86J	49-1069	1
YF-93A (orig. F-86C)	48-0316 / 48-0317	2
Total F-86A models		554
YF-86D (orig. YF-95)	50-0577 / 50-0578	2
F-86D-1	50-0455 / 50-0491	37
F-86D-5	50-0492 / 50-0517	26
F-86D-10	50-0518 / 50-0553	36
F-86D-15	50-0554 / 50-0576	23
F-86D-15	50-0704 / 50-0734	31
F-86D-20	51-2944 / 51-3131	188
F-86D-25	51-5857 / 51-5944	88
F-86D-30	51-5945 / 51-6144	200
F-86D-35	51-6145 / 51-6262	118
F-86D-35	51-8274 / 51-8505	232
F-86D-40	52-3598 / 52-3897	300
F-86D-45	52-3898 / 52-4197	300
F-86D-50	52-4198 / 52-4304	107
F-86D-50	52-9983 / 52-10176	194
F-86D-55	53-0557 / 53-0781	225
F-86D-60	53-0782 / 53-1071	290
F-86D-60	53-3675 / 53-3710	36
F-86D-60	53-4018 / 53-4090	73
Total F-86D models		2,506
F-86E-1	50-0579 / 50-0638	60
F-86E-5	50-0639 / 50-0689	51
F-86E-6 (Canadair)	52-2833 / 52-2892	60
F-86E-10	51-2718 / 51-2849	132
F-86E-15	51-12977 / 51-13069	93
Total F-86E models		396

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Model	Serial Numbers	Total
F-86F-1	51-2850 / 51-2927	78
F-86F-5	51-2928 / 51-2943	16
F-86F-10	51-12936 / 51-12969	34
F-86F-15	51-12970 / 51-12976	7
F-86F-20	51-13070 / 51-13169	100
F-86F-25	51-13170 / 51-13510	341
F-86F-25	52-5272 / 52-5530	259
F-86F-30	52-4305 / 52-5163	859
F-86F-35	52-5164 / 525271	108
F-86F-35	53-1072 / 53-1228	157
F-86F-40	55-3816 / 55-4030	215
F-86F-40	55-4983 / 55-5047	65
Total F-86F models		2,239
F-86H-1	52-1975 / 52-1976	2
F-86H-1	52-1977 / 52-2089	113
F-86H-5	52-2090 / 52-2124	35
F-86H-5	52-5729 / 52-5753	25
F-86H-10	53-1229 / 53-1528	300
Total F-86H models		475
YF-86K	52-3630, 52-3804	2
F-86K	54-1231 / 54-1350	120
Total F-86K models		122
Total of all F-86 models		6,295

Northrop F-89 Scorpion

Model	Serial Numbers	Total
XP-89	46-678	1
YF-89A	46-679	1
Total F-89 prototypes		2
F-89A	No number, used for static tests	1
F-89A	49-2431 / 49-2438	8

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Total F-89A models		9
Model	**Serial Numbers**	**Total**
F-89B-1	49-2439 / 49-2441	3
F-89B-5	49-2442 / 49-2448	7
F-89B-10	49-2449 / 49-2462	14
F-89B-15	49-2464 / 49-2478	15
YF-89D	49-2463	1
Total F-89B models		40
F-89C-1	50-741 / 50-744	4
F-89C-5	50-745 / 50-751	7
F-89C-5	50-753 / 50-759	7
F-89C-10	50-760 / 50-774	15
F-89C-15	50-775 / 50-789	15
F-89C-20	50-790 / 50-804	15
F-89C-25	51-5757 / 51-5771	15
F-89C-30	51-5772 / 51-5801	30
F-89C-35	51-5802 / 51-5836	35
F-89C-40	51-5837 / 51-5856	20
YF-89E	50-752	1
Total F-89C models		164
F-89D-1	51-400 / 51-406	7
F-89D-5	51-407 / 51-426	20
F-89D-10	51-427 / 51-446	20
F-89D-15	51-11298 / 51-11317	20
F-89D-20	51-11318 / 51-11357	40
F-89D-25	51-11358 / 51-11407	50
F-89D-30	51-11408 / 51-11443	36
F-89D	No number, used for static tests	1
F-89D-35	52-1829 / 52-1868	40
F-89D-40	52-1869 / 52-1910	42
F-89D-45	52-1911 / 52-1961	50
F-89D-45	52-2127 / 52-2165	40
F-89D-50	53-2447 / 53-2461	15
F-89D-55	53-2462 / 53-2521	60
F-89D-60	53-2522 / 53-2581	60
F-89D-65	53-2582 / 53-2641	60
F-89D-70	53-2642 / 53-2686	45
F-89D-75	54-184 / 54-260	77

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Total F-89D models		683

Model	Serial Numbers	Total
F-89H-1	54-261 / 54-320	60
F-89H-5	54-321 / 54-416	96
F-89H	No number, used for static tests	1
Total F-89H models		157
F-89J	Modified from F-89D-35 through F-89D-70 blocks	350
Total of all F-89 machines (does not include J models, as they are counted as Ds)		1,055

Lockheed F-94 Starfire

Model	Serial Numbers	Total
YF-94 (converted TF-80Cs)	48-356 / 48-357	2
F-94A-1	49-2479 / 49-2495	17
F-94A-5	49-2496, 49-2498 / 49-2588	92
YF-94B	49-2497	1
Total F-94A models		110
F-94B-1	50-805 / 50-876	72
F-94B-1	50-878 / 50-954	77
F-94B-5	51-5307 / 51-5512	206
YF-94C	50-877, 50-955	2
Total F-94B models		357
F-94C-1	50-956 / 50-1063	108
F-94C-1	51-5513 / 51-5698	186
F-94C-1	51-13511 / 51-13603	93
Total F-94C models		387
Total of all F-94 machines		856

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Technical Specifications

Notes

The following statistics are intended primarily for comparative purposes, and should not be taken as absolutes. These statistics were compiled from a variety of sources, which frequently disagreed with each other. Even such seemingly 'hard' information such as the physical dimensions of the aircraft can vary significantly depending on the source. Performance data is even more suspect, as such measurement is subject to a wide number of variables, which can significantly alter the results.

Another important fact to consider is that performance data usually represents ideal performance, obtained under optimal test circumstances. Such tests were typically done with a 'clean' aircraft, that is, a relatively new one, with a minimum of extra weight and drag. This meant no ammunition for the weapons, no external ordinance such as bombs or rockets, and no external fuel tanks (except for maximum range data.) Such test aircraft were also well maintained. Any or all of these conditions could be different in an operational unit, particularly in a combat environment.

Definitions and explanations of the individual categories are as follows. If three dashes are listed (---), it means than no data was available for that aircraft in that category.

Engine — Lists the official Air Force designation of the engine(s). If multiple engines of that type were used, designation will be preceded by a numeric indicator [ex. - 2 x]. More than one type of engine may be listed. If the first is followed by 'and', then the different types of engines were carried simultaneously. If the first is followed by 'or', then the different types represent upgraded engines introduced during the production run.

Thrust — Lists the power available from the engine. If the plane is powered by more than one engine, power output given is for a single engine. Usually listed in terms of pounds of static thrust (s.t.), although piston engines have horsepower (h.p.) listed. If some form of power augmentation is available, that is listed below the basic thrust. This would normally come from an afterburner (a.b.), but on several early models may also include water injection (w.i.).

Wingspan — Distance between the wing tips (includes tip tanks, if attached).

Length — Distance between the nose and tail of the aircraft.

Height — Distance to the tallest point of the aircraft, when it is parked on the ground.

Empty Weight — The minimum weight of the finished aircraft. This does *not* include such things as fuel, ammunition, external stores, or the pilot.

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Gross Weight The weight of the aircraft when equipped with a standard (not maximum) load of fuel, ammunition, and external stores.

Maximum Weight The maximum weight possible which will still allow the aircraft to take off. Usually in the form of extra fuel or external ordinance. An aircraft at the maximum weight will have severe performance penalties, such as decreased speed and endurance.

Maximum speed The best speed attainable in level flight.
at The altitude at which that speed can be obtained. If the altitude is listed as '100 ft', then the speed is for sea level. Maximum speed can vary by as much as 100 mph, depending on the altitude. Carrying external stores (fuel, weapons) can also reduce maximum speed.

Climb to Altitude measured in feet, beginning from sea level.
in The time it takes the aircraft to reach that altitude, expressed in minutes.

Climb in 1 minute The height above sea level the aircraft can reach in one minute.

Service ceiling The height above sea level at which the aircraft is unable to climb faster than 100 feet per minute. Note that this is *not* the same as absolute ceiling, which is the maximum altitude at which the aircraft can maintain level flight, or as combat ceiling, which is the maximum altitude at which the aircraft can maintain a climb rate of 500 feet per minute. Service ceiling was chosen because this is the most commonly used measure of an aircraft's altitude capacity. An aircraft's combat and absolute ceilings may vary a great deal from the service ceiling, or be very close to it.

Range The distance the aircraft can fly, using internal fuel only.

Maximum range The maximum distance the aircraft can fly, using maximum fuel load (including external fuel tanks), at the best altitude and using the most economical fuel settings for the engine. It is vital to recognize that range is not the same as *combat radius*. Range is simply taking off and flying from one point to another. Combat radius is the distance the plane can cover when it is fully equipped for a combat mission, takes off, flies a certain distance, engages in combat (which means increased speed and fuel consumption) and then returns to its original base. Combat radius, then, is typically half or less of the normal (not maximum) range.

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Armament The various weapons carried by the aircraft. Internally carried weapons are listed normally. If the weapons were proposed but never installed, as was common with many prototypes, they are listed in parenthesis (). Weapons listed in brackets [] are carried externally. Externally carried weapons are listed in maximum quantities, and may be carried in combination with other types (ex. - bombs and rockets carried together).

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Technical Specifications

	XP-59A	P-59A	P-59B
Engine	2 x GE I-A	2 x J31-GE-3	2 x J31-GE-5
Thrust	1,250 lb s.t.	1,650 lb s.t.	2,000 lb s.t.
Wingspan	45 ft 6 in	45 ft 6 in	45 ft 6 in
Length	38 ft 2 in	38 ft 10 in	38 ft 10 in
Height	12 ft 4 in	12 ft	12 ft
Empty weight	7,320 lb	7,950 lb	8,165 lb
Gross weight	---	10,822 lb	11,040 lb
Maximum weight	12,562 lb	13,000 lb	13,700 lb
Maximum speed **at**	404 mph 25,000 ft	413 mph 30,000 ft	413 mph 30,000 ft
Climb to **in**	--- ---	30,000 ft 15.5 min	30,000 ft 15.5 min
Climb in 1 minute	---	3,200 ft	---
Service ceiling	45,756 ft	46,200 ft	46,200 ft
Range	---	375 mi	375 mi
Maximum range	---	550 mi	950 mi
Armament	(2 x 37 mm cannon)	1 x 37 mm cannon 3 x .5 in machine guns [8 x 5 in rockets, or] [2 x 1,000 lb bombs]	1 x 37 mm cannon 3 x .5 in machine guns [8 x 5 in rockets, or] [2 x 1,000 lb bombs]

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Technical Specifications

	XP-67	XP-79B
Engine	2 x Continental X1-1430, and 2 x turbosuperchargers	2 x Westinghouse 19B
Thrust	1,350 hp	1,365 lb s.t.
Wingspan	55 ft	38 ft
Length	44 ft 9 in	14 ft
Height	15 ft 9 in	7 ft
Empty weight	17,745 lb	5,840 lb
Gross weight	23,114 lb	8,669 lb
Maximum weight	25,400 lb	---
Maximum speed at	405 mph 25,000 ft	547 mph 25,000 ft
Climb to in	25,000 ft 17 min	25,000 ft 4.7 min
Climb in 1 minute	2,600 ft	---
Service ceiling	37,400 ft	40,000 ft
Range	---	993 mi
Maximum range	2,384 mi	---
Armament	(6 x 37 mm cannon)	(4 x .5 in machine guns)

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Technical Specifications

	XP-80	XP-80A	P-80A
Engine	de Haviland H.1B Goblin	J33-GE	J33-GE-11
Thrust	2,460 lb s.t.	4,000 lb s.t.	3,850 lb s.t.
Wingspan	37 ft	39 ft	38 ft 10 in
Length	32 ft 10 in	34 ft 6 in	34 ft 6 in
Height	10 ft 3 in	11 ft 4 in	11 ft 4 in
Empty weight	6,284 lb	7,225 lb	7,920 lb
Gross weight	8,620 lb	9,600 lb	11,700 lb
Maximum weight	9,916 lb	13,780 lb	14,000 lb
Maximum speed at	502 mph 20,480 ft	553 mph 5,700 ft	558 mph 100 ft
Climb to in	10,000 ft 3.7 min	20,000 ft 4.6 min	20,000 ft 5.5 min
Climb in 1 minute	3,000 ft	---	4.580 ft
Service ceiling	41,000 ft	48,500 ft	45,000 ft
Range	1,000 mi	560 mi	780 mi
Maximum range	---	1,200 mi	1,440 mi
Armament	6 x .5 in machine guns	6 x .5 in machine guns	6 x .5 in machine guns [10 x 5 in rockets, or] [2 x 1,000 lb bombs]

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Technical Specifications

	P-80B	F-80C	TF-80C
Engine	J33-A-21	J33-A-23/35	J33-A-33
Thrust	4,600 lb s.t. 5,200 lb w.i.	4,600 lb s.t. 5,200 lb w.i.	4,600 lb s.t. 6,000 lb a.b.
Wingspan	39 ft	38 ft 10 in	38 ft 11 in
Length	34 ft 6 in	34 ft 5 in	40 ft 1 in
Height	11 ft 4 in	11 ft 3 in	12 ft 8 in
Empty weight	8,176 lb	8,420 lb	9,557 lb
Gross weight	12,200 lb	12,200 lb	12,919 lb
Maximum weight	16,000 lb	16,856 lb	15,330 lb
Maximum speed **at**	577 mph 6,000 ft	594 mph 100 ft	606 mph 100 ft
Climb to **in**	--- ---	25,000 ft 7 min	--- ---
Climb in 1 minute	6,475 ft	6,870 ft	11,274 ft
Service ceiling	45,500 ft	46,800 ft	49,500 ft
Range	790 mi	825 mi	---
Maximum range	1,210 mi	1,380 mi	1,079 mi
Armament	6 x .5 in machine guns [10 x 5 in rockets, or] [2 x 1,000 lb bombs]	6 x .5 in machine guns [10 x 5 in rockets, or] [4 x 1,000 lb bombs, or]	---

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Technical Specifications

	XP-81	XP-83
Engine	XT31-GE-1 turboprop, and J33-GE-5	2 x J33-GE-5
Thrust	2,300 hp 3,750 lb s.t.	4,000 lb s.t.
Wingspan	50 ft 6 in	53 ft
Length	44 ft 8 in	44 ft 10 in
Height	13 ft 6 in	15 ft 3 in
Empty weight	12,755 lb	14,105 lb
Gross weight	19,500 lb	24,090 lb
Maximum weight	24,650 lb	27,500 lb
Maximum speed **at**	507 mph 30,000 ft	522 mph 15,660 ft
Climb to **in**	30,000 ft 7 min	30,000 ft 11.5 min
Climb in 1 minute	5,300 ft	5,650 ft
Service ceiling	35,500 ft	45,000 ft
Range	---	1,730 mi
Maximum range	2,500 mi	2,050 mi
Armament	(6 x .5 in machine guns, or) (6 x 20 mm cannon)	(6 x .5 in machine guns) [2 x 1,000 lb bombs]

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Technical Specifications

	XP-84	P-84B	P-84D
Engine	J35-GE-7	J35-A-15C	J35-A-17D
Thrust	3,750 lb s.t.	4,000 lb s.t.	5,000 lb s.t.
Wingspan	36 ft 5 in	36 ft 5 in	36 ft 5 in
Length	37 ft 5 in	37 ft 5 in	37 ft 5 in
Height	12 ft 7 in	12 ft 10 in	12 ft 10 in
Empty weight	9,080 lb	9,538 lb	9,860 lb
Gross weight	---	13,465 lb	13,894 lb
Maximum weight	16,200 lb	19,689 lb	20,076 lb
Maximum speed at	592 mph 100 ft	587 mph 4,000 ft	587 mph 4,000 ft
Climb to in	---	---	---
Climb in 1 minute	---	5,200 ft	4,060 ft
Service ceiling	40,750 ft	40,750 ft	39,300 ft
Range	---	1.282 mi	1,198 mi
Maximum range	---	---	---
Armament	(6 x .5 in machine guns)	6 x .5 in machine guns [32 x 5 in rockets, or] [2 x 12 in rockets, or] [2 x 250 lb bomb]	6 x .5 in machine guns [32 x 5 in rockets, or] [2 x 12 in rockets, or] [2 x 250 lb bomb]

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Technical Specifications

	F-84E	F-84F	F-84G
Engine	J35-A-17	J65-W-1/3/7	J35-A-29
Thrust	5,000 lb s.t.	7,220 lb s.t.	5,000 lb s.t.
Wingspan	36 ft 5 in	33 ft 7 in	36 ft 5 in
Length	38 ft 7 in	43 ft 5 in	38 ft 7 in
Height	12 ft 10 in	14 ft 5 in	12 ft 10 in
Empty weight	10,205 lb	13,800 lb	11,095 lb
Gross weight	14,724 lb	18,700 lb	18,645 lb
Maximum weight	22,463 lb	28,000 lb	23,525 lb
Maximum speed **at**	613 mph 100 ft	695 mph 100 ft	622 mph 100 ft
Climb to **in**	--- ---	35,000 ft 7.8 min	35,000 ft 9.4 min
Climb in 1 minute	6,061 ft	8,200 ft	---
Service ceiling	43,220 ft	36,150 ft	40,500 ft
Range	1,485 mi	860 mi	---
Maximum range	1,950 mi	2,314 mi	2,000 mi
Armament	6 x .5 in machine guns [32 5 in rockets, or] [2 x 12 in rockets,or] [2 x 1,000 lb bombs]	6 x .5 in machine guns [2 x 2,000 lb bombs, and] [2 x 1,000 lb bombs]	6 x .5 in machine guns [32 x 5 in rockets, or] [2 x 12 in rockets, or] [2 x 2,000 lb bombs]

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Technical Specifications

	XF-85	XF-87	XF-88
Engine	J34-WE-7	4 x J34-WE-7	2 x J34-WE-13
Thrust	3,000 lb s.t.	3,000 lb s.t.	3,000 lb s.t.
Wingspan	21 ft 1 in	60 ft	39 ft 8 in
Length	14 ft 10 in	62 ft 10 in	54 ft 1 in
Height	8 ft 3 in	20 ft	17 ft 3 in
Empty weight	3,740 lb	25,930 lb	12,140 lb
Gross weight	4,550 lb	37,350 lb	18,500 lb
Maximum weight	---	49,900 lb	23,100 lb
Maximum speed at	581 mph 35,000 ft	600 mph 100 ft	641 mph 100 ft
Climb to in	35,000 ft 5.1 min	35,000 ft 13.8 min	35,000 ft 14.5 min
Climb in 1 minute	12,500 ft	---	---
Service ceiling	48,200 ft	41,000 ft	36,000 ft
Range	30 min	1,000 mi	---
Maximum range	---	2,175 mi	1,737 mi
Armament	(4 x .5 in machine guns)	(4 x 20 mm cannon)	(6 x 20 mm cannon)

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Technical Specifications

	XP-86	F-86A	F-86D
Engine	J35-C-3, or J35-A-5	J47-GE-1/3/7/9/13	J47-GE-17, or J47-GE-33
Thrust	3,750 lb s.t. 3,920 lb s.t.	5,200 lb s.t.	5,425 lb s.t. 7,500 lb a.b. 5,500 lb s.t. 7,650 lb a.b.
Wingspan	37 ft	37 ft 1 in	37 ft 1 in
Length	37 ft 6 in	37 ft 6 in	40 ft 1 in
Height	14 ft 9 in	14 ft 9 in	15 ft
Empty weight	9,730 lb	10,093 lb	13,518 lb
Gross weight	13,790 lb	15,876 lb	18,183 lb
Maximum weight	16,438 lb	16,223 lb	19,975 lb
Maximum speed **at**	618 mph 14,000 ft	679 mph 100 ft	692 mph 100 ft
Climb to **in**	30,000 ft 12.1 min	40,000 ft 10.4 min	40,000 ft 7.2 min
Climb in 1 minute	---	7,630 ft	12,150 ft
Service ceiling	41,300 ft	48,000 ft	49,750 ft
Range	750 mi	660 mi	554 mi
Maximum range	---	1,052 mi	769 mi
Armament	(6 x .5 in machine guns)	6 x .5 in machine guns [16 x 5 in rockets, or] [2 x 1,000 lb bombs]	24 x 2.75 in rockets

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Technical Specifications

	F-86E	F-86F	F-86H
Engine	J47-GE-13, or J47-GE-27	J47-GE-27	J73-GE-3
Thrust	5,200 lb s.t 5,970 lb s.t.	5,970 lb s.t.	8,920 lb s.t.
Wingspan	37 ft	39 ft 1 in	39 ft 1 in
Length	37 ft	37 ft	38 ft 8 in
Height	14 ft	14 ft	15 ft
Empty weight	10,555 lb	10,815 lb	13,836 lb
Gross weight	16,346 lb	17,772 lb	21,852 lb
Maximum weight	17,806 lb	20,611 lb	24,296 lb
Maximum speed **at**	679 mph 100 ft	688 mph 100ft	692 mph 100 ft
Climb to **in**	30,000 ft 6.3 min	30,000 ft 5.2 min	--- ---
Climb in 1 minute	---	9,300 ft	12,900 ft
Service ceiling	47,200 ft	48,000 ft	50,800 ft
Range	848 mi	463 mi	519 mi
Maximum range	1,022 mi	1,317 mi	1,810 mi
Armament	6 x .5 in machine guns [16 x 5 in rockets, or] [2 x 1,000 lb bombs]	6 x .5 in machine guns [16 x 5 in rockets, or] [2 x 1, 000 lb bombs]	4 x 20 mm cannon, or 6 x .5 in machine guns [16 x 5 in rockets, or] [2 x 1,000 lb bombs]

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Technical Specifications

	XP-89	F-89A	F-89B
Engine	2 x J34-A-9	2 x J35-A-21A	2 x J35-A-21B
Thrust	4,000 lb s.t.	5,100 lb s.t. 6,800 lb a.b.	5,100 lb s.t. 6,800 lb a.b.
Wingspan	52 ft	56 ft	56 ft
Length	50 ft 5 in	53 ft 5 in	53 ft 5 in
Height	17 ft 8 in	17 ft 6 in	17 ft 6 in
Empty weight	25,864 lb	23,654 lb	23,654 lb
Gross weight	---	36,400 lb	36,400 lb
Maximum weight	43,910 lb	---	---
Maximum speed **at**	603 mph 2,500 ft	642 mph 100 ft	642 mph 100 ft
Climb to **in**	35,000 ft 21 min	--- ---	--- ---
Climb in 1 minute	---	10,800 ft	10,800 ft
Service ceiling	35,500 ft	50,000 ft	50,000 ft
Range	---	425 mi	425 mi
Maximum range	1,750 mi	1,300 mi	1,300 mi
Armament	(4 x 20 mm cannon)	6 x 20 mm cannon [16 x 5 in rockets, or] [2 x 1,500 lb bombs]	6 x 20 mm cannon [16 x 5 in rockets, or] [2 x 1,500 lb bombs]

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Technical Specifications

	F-89C	F-89D	F-89H
Engine	2 x J35-A-33	2 x J35-A-41	J35-A-35
Thrust	5,600 lb s.t. 7,400 lb a.b.	5,440 lb s.t. 7,200 lb a.b.	5,440 lb s.t. 7,200 lb a.b.
Wingspan	56 ft	60 ft 5 in	60 ft 5 in
Length	53 ft 5 in	53 ft 10 in	53 ft 10 in
Height	17 ft 6 in	17 ft 6 in	17 ft 6 in
Empty weight	24,570 lb	25,194 lb	25,194 lb
Gross weight	37,348 lb	42,241 lb	46,600 lb
Maximum weight	42,827 lb	46,780 lb	47,400 lb
Maximum speed **at**	650 mph 100 ft	636 mph 10,600 ft	630 mph 100 ft
Climb to **in**	--- ---	46,500 ft 18.1 min	46,500 ft 18.1 min
Climb in 1 minute	12,300 ft	8,360 ft	8,360 ft
Service ceiling	50,500 ft	49,200 ft	47,000 ft
Range	389 mi	382 mi	382 mi
Maximum range	905 mi	1,367 mi	1,367 mi
Armament	6 x 20 mm cannon [16 x 5 in rockets, or] [2 x 1,500 lb bombs]	104 x 2.75 in rockets	6 x Falcon missiles, and 42 x 2.75 in rockets

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Technical Specifications

	F-89J	XF-90
Engine	2 x J35-A-41	2 x J34-WE-15
Thrust	5,440 lb s.t. 7,200 lb a.b.	3,600 lb s.t. 4,200 lb a.b.
Wingspan	60 ft 5 in	40 ft
Length	53 ft 10 in	56 ft 2 in
Height	17 ft 6 in	15 ft 9 in
Empty weight	25,194 lb	18,050 lb
Gross weight	42,590 lb	27,200 lb
Maximum weight	47,719 lb	31,060 lb
Maximum speed **at**	636 mph 10,600 ft	688 mph 1,000 ft
Climb to **in**	--- ---	25,000 ft 4.5 min
Climb in 1 minute	8,360 ft	---
Service ceiling	43,500 ft	39,000 ft
Range	382 mi	1,050 mi
Maximum range	1,367 mi	2,300 mi
Armament	4 x Falcon missiles, and 2 x Genie nuclear missiles	(6 x 20 mm cannon)

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Technical Specifications

	XF-91	XF-92A	YF-93
Engine	J47-GE-3, and 4 x XLR-RM-9	J33-A-23 J33-A-29	J48-P-6
Thrust	5,200 lb s.t. 1,500 lb s.t.	4,600 lb s.t. 5,400 lb w.i. 5,900 lb s.t. 7,500 lb a.b.	6,000m lb s.t. 8,760 lb a.b.
Wingspan	31 ft 3 in	31 ft 3 in	38 ft 9 in
Length	43 ft 3 in	42 ft 5 in	44 ft 1 in
Height	18 ft 1 in	17 ft 8 in	15 ft 8 in
Empty weight	14,140 lb	9,078 lb	14,035 lb
Gross weight	18,600 lb	13,000 lb	21,610 lb
Maximum weight	28,300 lb	14,608 lb	26,516 lb
Maximum speed **at**	1,126 mph ---	718 mph 100 ft	708 mph 100 ft
Climb to **in**	47,500 ft 2.5 min	35,000 ft 4.3 min	--- ---
Climb in 1 minute	---	---	11,960 ft
Service ceiling	50,000 ft	50,000 ft	46,800 ft
Range	1,171 mi	---	1,967 mi
Maximum range	---	---	---
Armament	(4 x 20 mm cannon)	(4 x 20 mm cannon)	(6 x 20 mm cannon) [2 x 1,000 lb bomb]

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Technical Specifications

	F-94A	F-94B	F-94C
Engine	J33-A-33	J33-A-33A	J48-P-5
Thrust	4,600 lb s.t. 6,000 lb a.b.	4,600 lb s.t. 6,000 lb a.b.	6,350 lb s.t. 8,750 lb a.b.
Wingspan	38 ft 11 in	38 ft 11 in	42 ft 5 in
Length	40 ft 1 in	40 ft 1 in	44 ft 6 in
Height	12 ft 8 in	12 ft 8 in	14 ft 11 in
Empty weight	9,557 lb	10,064 lb	12,708 lb
Gross weight	12,919 lb	13,474 lb	18,300 lb
Maximum weight	15,330 lb	16,844 lb	24,184 lb
Maximum speed **at**	606 mph 100 ft	606 mph 100 ft	640 mph 100 ft
Climb to **in**	--- ---	--- ---	49,700 ft 19 min
Climb in 1 minute	11,274 ft	6,850 ft	7,980 ft
Service ceiling	49,500 ft	48,000 ft	51,400 ft
Range	---	665 mi	805 mi
Maximum range	1,079 mi	905 mi	1,275 mi
Armament	4 x .5 in machine guns [2 x 1,000 lb bombs]	4 x .5 in machine guns [2 x 1,000 lb bombs]	24 x 2.75 in rockets, or 48 x 2.75 in rockets

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Technical Specifications

	MiG-15	MiG-15bis
Engine	RD-45F	VK-1
Thrust	5,005 lb s.t.	5,952 lb s.t.
Wingspan	33 ft 1 in	33 ft 1 in
Length	32 ft 11 in	35 ft 7 in
Height	12 ft 1 in	12 ft 1 in
Empty weight	7,767 lb	8,115 lb
Gross weight	10,941 lb	11,861 lb
Maximum weight	---	---
Maximum speed **at**	652 mph 100 ft	688 mph 9,840 ft
Climb to **in**	16,405 ft 2.5 min	16,405 ft 1.95 min
Climb in 1 minute	---	---
Service ceiling	49,856 ft	50,840 ft
Range	730 mi	826 mi
Maximum range	992 mi	1,154 mi
Armament	1 x 37 mm cannon 2 x 23 mm cannon	1 x 37 mm cannon 2 x 23 mm cannon [2 x 220 lb bombs]

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