# LIGHTING THE FLAME


## The Turbojet Revolution Comes to America

*Front Cover Photo: Bell Test Pilot Jack Woolams cinching up his parachute harness just prior to entering the cockpit of a YP-59A at Muroc, 1943.*

*Back Cover Photo: A production model P-80A undergoing service tests at Muroc, early October 1945.*

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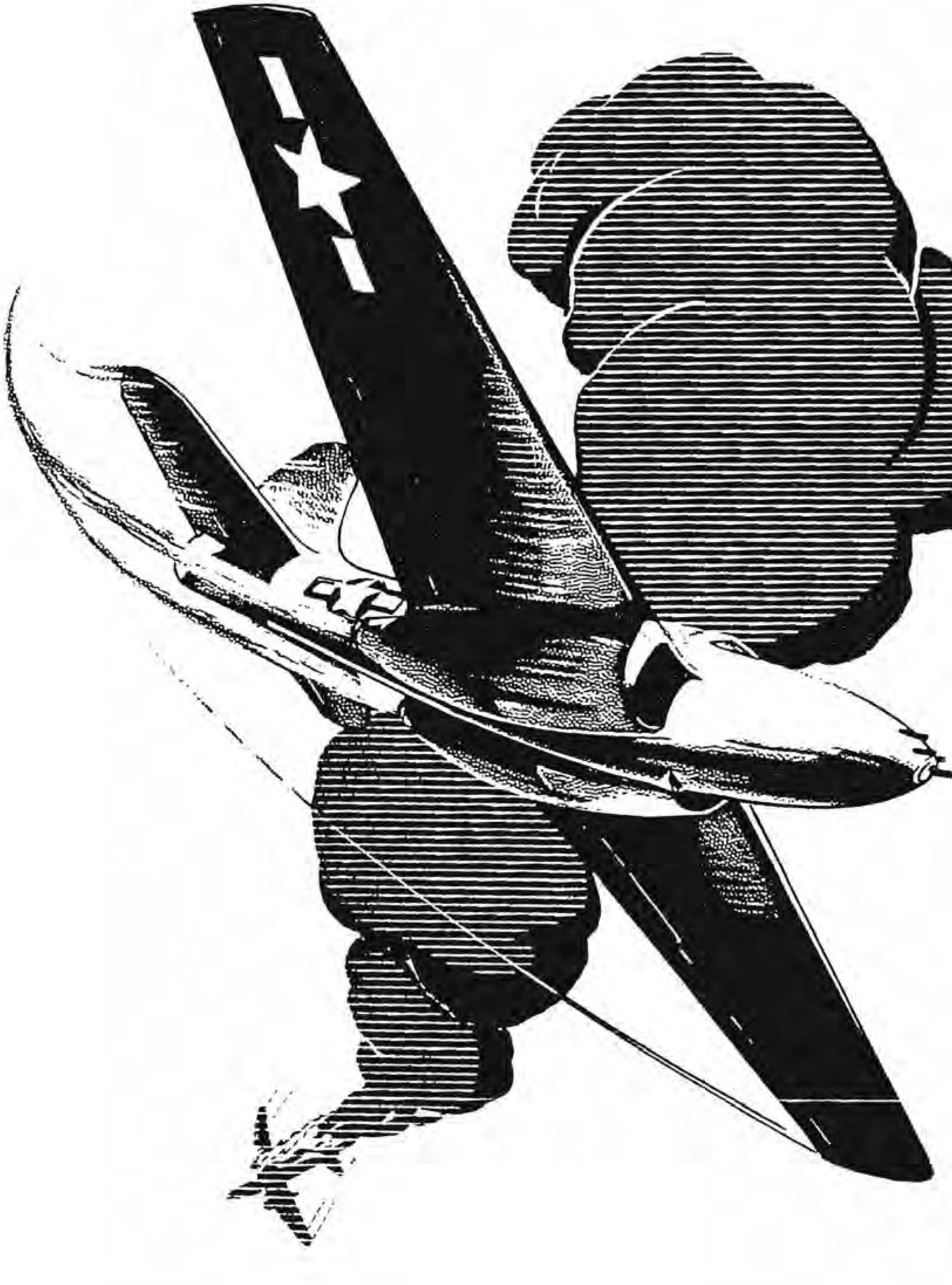

*Classic 1940s-era graphic artwork from the "Pilot's Flight Operating Instructions" manual for the P-59A and P-59B. The dramatic combat scene reflects a bit of wishful thinking on the part of the Bell Aircraft Corporation artist who produced it. The P-59 was never destined for combat service.*

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## The Turbojet Revolution Comes to America

In 1928, 21-year old Royal Air Force (RAF) flight cadet Frank Whittle speculated that it would be possible to attain very high speeds—speeds in excess of 500 mph—if one could achieve stratospheric flight. He also perceived that the piston-engined, propeller-driven airplane would never do the job. To achieve the speed and altitude he envisioned, some alternate form of propulsion system uniquely suited to those conditions was absolutely essential. His deductions were prophetic.

### *Piston Engines – "An Invention of the Devil"*

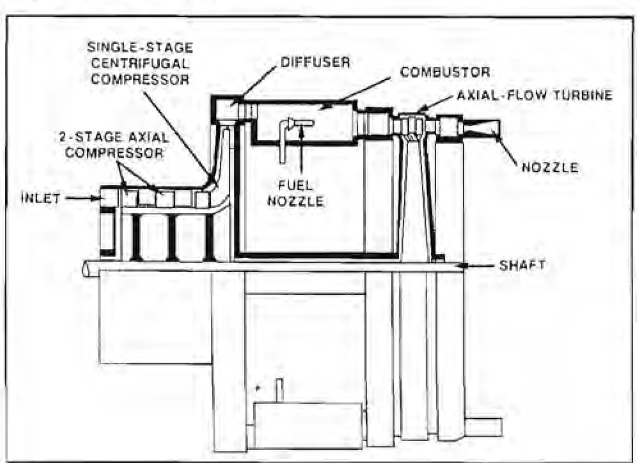
During the 1930s, the prop-driven, piston-engined airplane underwent a dramatic metamorphosis. Streamlined, all-metal, light-weight, monocoque fuselages, retractable landing gear and a host of other airframe innovations reduced aircraft weight and drag to previously unimagined levels. And the engines? The Wright Brothers had powered their first airplane with an engine providing about 12 horsepower—or one horsepower per 15 pounds of engine weight. By the early years of World War II, engine designers would be squeezing more than 2,000 horsepower out of the churning pistons of their evermore complex, turbo-supercharged combat designs (by the end of the war, the Wasp Major would be delivering up to 3,500 hp) and they had achieved a power-to-weight ratio of better than one-to-one. To fully exploit all of this power, there had been major improvements in fuels and propeller design, as well. During the 30s, for example, the U.S. Army Air Corps adopted 100 octane fuel and prop designers had developed aerodynamically efficient, variable-pitch propellers which could be adjusted, in flight, for optimum performance at different speeds and altitudes.

In their quest for ever greater speeds during the 1930s, designers came up with aircraft that appeared to be little more than engines with empennage and wings. And, indeed, the world speed record leaped upward throughout the decade following Whittle's original speculations. Perhaps no aircraft better epitomized this trend than Willie Messerschmitt's Me 209V-1 which, in April of 1939, pushed the record all the way to 469.22 mph (although unofficially surpassed during the coming war, this mark would remain the official record for the next three decades). For all intents and purposes, the Me 209 defined the practical limits of prop-driven aircraft. Its engine, the 12-cylinder, liquid-cooled Daimler-Benz DB 601ARJ, provided 1,800 hp—and could be boosted up to 2,300 hp for short bursts—but it had a service life of only 30 minutes. And, like so many of its kind, the Me 209 was extremely difficult to fly; its pilot, Fritz Wendel, later recalling that it "was a brute. Its flying characteristics still make me shudder...In retrospect, I am inclined to think that its main fuel was a highly volatile mixture of sweat from my brow and the goose pimples from the back of my neck!"

Aero-engine pioneer Ernest Simpson once described the reciprocating engine as "an invention of the devil." Although marvelous examples of mechanical ingenuity and precision engineering, they were infernally complicated and temperamental. Maintenance was "difficult, frequent, and often painful." Added to this was the fact that, by the late 30s, designers found themselves caught in a vicious circle. Higher speeds required ever-larger engines which consumed greater amounts of fuel and resulted in larger and heavier airframes whose size and weight served to negate the increased performance of the engines. And the engines themselves—whether air- or liquid-cooled—posed monumental problems. In air-cooled engines, for example, the peak power output of an individual cylinder was something less than 175 horsepower and thus, to boost power, designers were forced to add more and more pistons to a single crankshaft. The ever-increasing mechanical complexity of such linkages became an engineering and maintenance nightmare. Moreover, each additional row of cylinders had a detrimental impact on thermal efficiency. Instead of converting the engine's heat into useful mechanical work (i.e., power to drive the propeller), much of it—along with the airplane's aerodynamic efficiency, as well—had to be wasted in the cooling of these behemoths. Propellers also created seemingly insurmountable problems. As their blade tips approached supersonic speeds, for example, they encountered "compressibility burble"—shock waves that caused an unacceptable increase in drag—and, as the air thinned out with increasing altitude, props lost their "bite."

The field of aeronautics was approaching a crossroads by the mid 30s. Aerodynamicists, who had made such great strides since the mid 20s, were pointing in a new direction. Indeed, at the Fifth Volta Congress of High Speed Flight, which met at Campidoglio, Italy, in 1935, the world's leading aerodynamicists began to seriously consider the theoretical possibility of flight beyond the speed of sound. It was readily apparent to those assembled that the piston engine-prop combination could never meet that challenge. It was also becoming apparent to many that, in the not too distant future, the reciprocating engine would reach a plateau beyond which only minutely small improvements in performance could be expected in return for enormous expenditures in terms of time, money and engineering effort.

*Above: RAF Cadet Frank Whittle. Below: Figure 1 – Cutaway image based on Whittle's patent drawing for his 1930 engine design.*




## *An Idea,...Elegant in Its Simplicity*

Though he certainly had not considered the possibility of supersonic flight, Frank Whittle had forecast many of these developments in 1928 and, while undergoing flight instructor's training the following year, he saw the solution, not in any refinements to the existing technology, but in a radically new approach. He had already rejected rocket propulsion and a gas turbine-driven prop as impractical. Next, he had examined the possibility of a ducted-fan system—a jet propulsion system in which a conventional piston engine powered a low-pressure blower. The blower and engine would both be located in the duct and fuel would be burned in the flow stream aft of the engine to generate thrust. He had concluded, however, that this system would be far too heavy and would, in fact, offer no real advantage over the piston engine-prop combination. Then, in late 1929, as he later recalled, "the penny dropped":

> ...it suddenly occurred to me to substitute a turbine for the piston engine [in the ducted fan system]. This change meant that the compressor would have to have a much higher pressure ratio than the one I had visualized for the piston-engined scheme. In short, I was back to the gas turbine, but this time of a type which produced a propelling jet instead of driving a propeller. Once the idea had taken shape, it seemed rather odd that I had taken so long to arrive at a concept which had become very obvious and of extraordinary simplicity.

Thus, after less than two years of self-directed study and speculation, he had deduced that, for very high speeds and altitudes, employing a gas turbine to produce jet propulsion was the most feasible—and, ultimately, obvious—answer. As originally conceived in his patent application of 1930 (Figure 1): air entered the engine inlet and was initially compressed by a two-stage axial compressor and then further compressed by a single-stage, one-sided centrifugal compressor; after passing through a diffuser which transformed its kinetic energy into pressure, the highly compressed air entered a ring of combustors into which fuel was injected and then ignited; the hot, expanding gases were then expelled at high velocity through a two-stage axial-flow turbine, which drove the compressor stages by means of a shaft, and then exited through a ring of nozzles to produce forward thrust. With all of its moving parts on a single rotating shaft, Whittle believed, it would be much simpler and far lighter than piston engines.

Like so many revolutionary breakthroughs, Whittle's idea was elegant in its simplicity...and, like so many such ideas, it was scorned by the "experts" as impractical. He had not been the first to speculate about the possibility of employing a gas turbine for aircraft propulsion. The idea had been studied throughout the 1920s, though usually in the context of employing a turbine to drive a propeller. Based upon the generally negative findings of these studies, conventional wisdom scoffed at Whittle's proposal: compressor and turbine efficiencies would be insufficient; the temperatures and stresses imposed on a constant-pressure gas turbine would far exceed the capabilities of materials then in existence; the weight of any such engine would far exceed its thrust, and so on. They characterized his proposal as visionary, a very long-term proposition, at best.

Whittle, on the other hand, believed that the application of modern aerodynamic theory would permit virtually quantum increases in compressor and turbine efficiencies and that lightweight, heat- and stress-resistant alloys could be developed which would enable him to achieve adequate thrust-to-weight ratios in the near term. Moreover, the combined effects of ram air at high speeds and low temperatures at altitude would augment the work of the compressor, making a jet engine vastly more efficient the faster and higher an aircraft flew. Scoffers there were aplenty and, in what has to rank as one of history's prime examples of official obtuseness, the British Air Ministry denied his request for a modest amount of funding to support development of the concept.

By late 1935, he still had not overcome official apathy but, after having all but given up, he had finally secured an extremely modest amount (about $10,000) of private funding to begin the design of an engine for bench tests. By March of 1937, his backers had managed to increase the total to about $30,000 and his first bench-test engine, the W.U. (Whittle Unit), was ready for its initial test run. It was an incredibly ambitious undertaking. Whittle set out to build an engine that would produce 1,200 pounds of thrust at 17,500 rpm. At a time when the most efficient supercharger compressors were capable of compressing about 120 pounds of air per minute to a pressure of about twice that of the atmosphere, he strove for one which could handle 1,500 pounds per minute and achieve a remarkable 4:1 pressure ratio. He dispensed with the upstream axial compressor stages and employed a single-stage double-sided centrifugal compressor in order to achieve the hoped-for 4:1 compression ratio within a relatively small-diameter area. Surrounding the compressor impeller was a scroll-type volute leading into a vertical expanding diffuser pipe containing a honeycomb of divergent channels. At the top of the diffuser the air was turned 90 degrees by a cascade of vanes in an elbow before it entered the single combustion chamber. Once ignited, the expanding gases were to exit through a nozzleless scroll-shaped turbine inlet into a single-stage axial-flow turbine that was supposed to provide just over 3,000 hp to drive the compressor (or more than the net power then produced by any piston engine). While he felt confident he could achieve the targeted compressor and turbine efficiencies, Whittle was somewhat daunted when informed by experts that the combustion intensities for which he was striving were at least 20 times greater than had ever before been achieved.

On April 12, 1937, he ran up the W.U. for the first time...and it nearly blew apart! For the next two years, he struggled with burned out combustors, erratic fuel pressures, turbine failures and a host of other problems. Indeed, during that span, he had to completely rebuild the W.U. three times with leftover parts and whatever new components his meager funds would permit. The odds he faced were almost insurmountable but Whittle was doggedly determined and, very patiently and ever so slowly, he began to overcome them as, with each engine reconstruction, he incorporated significant modifications. As he had intended, for example, he applied theoretical aerodynamics to the design of his turbine and, with the third version of the engine, was able to convincingly demonstrate the advantages of a "free-vortex" design. Each blade was fabricated with a twist in it to compensate for differential radial velocity and pressure across its diameter, and this produced dramatic improvements in turbine efficiency.

## *Meanwhile, in Germany...*

Meanwhile, and although Whittle was completely unaware of it, hundreds of miles to the east, a brilliant young German physicist was also developing a jet engine of his own design. Based on his study of aerodynamics, Dr. Hans von Ohain had deduced that modern streamlining and structural theory would permit speeds much higher than those possible with the piston engine-prop combination and thus, like Whittle, he had concluded that a radical new form of propulsion—one uniquely suited for high-speed flight—would be required to exploit the full potential of airframe design. Although he had independently conceived the idea of a gas turbine-driven centrifugal-flow jet propulsion

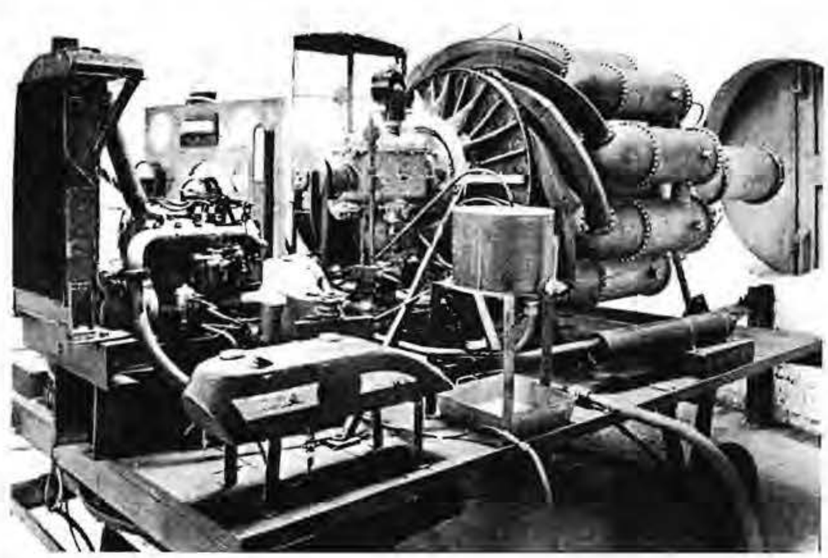
*Top: Ernst Heinkel (left) and Dr. Hans von Ohain. Center: the Heinkel He 178. Bottom: the Me 262.*

engine much later than Whittle, von Ohain had the good fortune to catch the attention of aircraft manufacturer Ernst Heinkel. And, in stark contrast to Whittle's impoverished circumstances, his efforts to build a bench-test engine were handsomely subsidized by the enthusiastic Heinkel. Employing hydrogen as fuel and providing a thrust of about 550 pounds, von Ohain's engine was actually tested, for the first time, about a month before Whittle's first unit and the success of these tests led to the development of a flight-rated engine and a small single-engined experimental airplane. Powered by von Ohain's 1,100-pound thrust He S-3b on August 27, 1939, the Heinkel He 178 became the first jet-powered aircraft ever to take to its wings.

Even before this flight, however, official government interest had long since entered into the equation. For, unlike the situation in England, a number of other German engineers—both in industry and government—had also already perceived the virtues of the turbojet solution. Most notable among them were Herbert Wagner and Max Adolph Muller of the Junkers Aircraft Company, and Helmut Schelp of the German Air Ministry. By mid-1937, Wagner and Muller had settled on the turbojet as "the shortest path to high aircraft speeds" and, by the end of the year, they had an engine under test. Unlike Whittle and von Ohain, their very meticulous studies had indicated that an axial-flow compressor was preferable because it would permit the straightest possible path for the air to flow through the engine and it would offer the advantages of a much smaller diameter and lower drag than a centrifugal flow design.

Schelp had arrived at the same conclusion by mid-1937 and, by early 1939, he had engaged all four of the major German engine manufacturers (Daimler-Benz, Junkers Motors, B.M.W. and Bramo) in reaction propulsion programs. By the fall of that year, Junkers was well along in the initial development of a design that would ultimately evolve into the Jumo 004B, an axial flow engine producing 1,980 pounds of thrust that would begin to enter mass production in the spring of 1944. And, equally important, by the fall of 1939, Schelp had also already been instrumental in issuing Messerschmitt a contract to design and develop a twin-engine turbojet interceptor which, within five years, would begin to make a name for itself in the skies over western Europe.

Thus, even before a turbojet-powered aircraft had yet flown, the German military had already begun to sponsor a massive effort aimed at the development of jet-powered combat airplanes. Unlike the British (and, later, the Americans), the Germans focused on the development of more efficient axial-flow engines from the outset. They were to suffer, however, from a severe shortage of skilled workers and, even more important, a near-total lack of the high-grade metals and alloys which were so essential to the development of efficient turbines and combustors. As a result, their engines were frequently inferior both in terms of materials and design. Thus, while designed for a modest service life of 25-35 hours, the Jumo 004B seldom exceeded ten hours of flying time in actual practice. Nevertheless, German efforts would bear fruit in a whole series of turbojet-powered aircraft that would actually enter combat service. The most notable of these was the sleek Me 262, the twin-engine, sweptwing fighter first conceived back in 1939. Capable of speeds in excess of ***540*** mph, the Me 262 would be unleashed with devastating effect against American bomber formations over western Europe by the fall of 1944.



***Top: The second reconstruction of Whittle's engine in 1938 featured ten separate combustion chambers. Bottom: the Gloster E.28/39.***

## *Whittle's Triumph—Arnold's Surprise*

Whittle was completely unaware of any of these efforts when, after a successful 20-minute demonstration of the third reconstruction of his engine to the Air Ministry in late June of 1939, he finally won official support and, with that, came the go-ahead to build a flight-rated engine which would be designated the W.1. The ministry also approved the design and construction of a small single-engined experimental airplane, the Gloster E.28/39. With its W.1 unit weighing only 623 pounds and providing almost 1,000 pounds of thrust, this airplane completed its maiden flight on May 15, 1941. Curiously, and even though approval had already been granted to proceed with the development of an up-rated engine to be known as the W.2B which would power the twin-engined Gloster Meteor, an official request to have the event filmed was inexplicably ignored. Some poor quality motion picture film of this milestone event survives only because someone violated security regulations and shot it with his own camera!

***Major General Henry H. "Hap" Arnold, then Chief of the U.S. Army Air Corps, went on to become the first and only five-star General of the Air Force.***

Among those on hand to witness the early taxi tests of the E.28/39 in April of 1941, however, was an American who ***was*** very interested and, indeed, shocked by the enormous potential promised by the new propulsion system. Chief of the U.S. Army Air Corps Major General H.H. "Hap" Arnold had been informed of British efforts the previous September and, prompted by alarming intelligence reports of German work in reaction propulsion, he had already launched a high-level inquiry into the subject. On February 25, 1941, he had asked Dr. Vannevar Bush, then chairman of both the National Defense Research Committee and the National Advisory Committee for Aeronautics (NACA), to establish a special committee of leading scientists to undertake this effort. Bush, in turn, had asked 82-year old Dr. William F. Durand, the "dean" of the American engineering community, to head up such an effort under the auspices of the NACA and, by April, the Special Committee on Jet Propulsion commenced its investigation with tentative inquiries into the potential of rocket-assisted takeoff, turbine-driven props and ducted fan engines. But, by that time, Arnold had already witnessed the pure jet Whittle engine in operation on an airplane and he was absolutely stunned by how far the British had advanced. And, if the British had done it, he reasoned, there could be little doubt that the Germans were at least as far along.

## *"Not Invented Here"...Why?*

The fact that the United States lagged behind Great Britain and Germany and was, indeed, taken by surprise has been described as the "most serious inferiority in American aeronautical development which appeared during the Second World War." And it has inevitably raised the question: why?

In his pioneering study, *Development of Aircraft Engines* (1950), Robert Schlaifer concluded that it was "simply the result of a historical accident: Whittle, von Ohain, and Wagner were not Americans." In his penetrating and highly interpretive analysis, *The Origins of the Turbojet Revolution* (1980), Edward Constant considered this a "catastrophically inadequate" explanation and argued, instead, that the reason could be found in different national-cultural approaches to science and technology. The British and, particularly, the Germans were steeped in a tradition of theoretical science that encouraged fundamental research into such areas as high-speed aerodynamics and axial-turbo compressor phenomena. They were mentally and psychologically prepared to question the basic assumptions of aeronautical science and thus England and Germany became natural spawning grounds for bold leaps into the unknown—for truly radical innovations such as the turbojet. The United States, on the other hand, "was possessed of a scientific tradition extreme in its empiricism and utilitarianism." The emphasis, Constant persuasively argued, was not on theory but on applied research leading to incremental refinements to existing technology. With a focus almost exclusively on immediately obtainable results, Americans excelled at subsonic aerodynamics, squeezing more and more horsepower out of piston engines, and achieving ever greater efficiencies in propeller design. Thus, while Europeans were exploring the high-speed frontier and even looking over the horizon toward supersonic flight, Americans were focused on the here-and-now as they built the best commercial airline system in the world. Apart from a small group of immigrants, such as the Hungarian-born and German-trained Theodore von Karman, American scientists and engineers were generally ill equipped to question the assumptions upon which the existing technology was based because their whole techno-cultural orientation was focused on palpable, here-and-now solutions to immediate problems. "The object," Consta t concluded, "was flight, not science, practice, not theory."

The whole question of why the turbojet was "not invented here" may never be answered to everyone's complete satisfaction. But, apart from national pride, it is not nearly so important as why the United States was so tardy in adopting and developing the new technology even after its revolutionary implications had become so clear to so many within the aeronautical community in this country. General Arnold and other Air Corps commanders may have been taken by surprise (though they should not have been) but an awareness of the potential offered by—and, indeed, the necessity for — some form of jet propulsion was fairly widespread in this country, especially after the 1935 Volta Congress on high-speed flight. During the late 30s, for example, Ezra Kotcher was serving as the senior instructor at the Air Corps Engineering School at Wright Field, Ohio. While specializing in aerodynamics, he was well enough versed in *all* fields to be able to teach most of the academic curriculum and he was widely regarded as one of the few truly brilliant aeronautical engineers at Wright Field. Looking back on that period, he recalled with a certain amount of sarcasm that "it reached the point that you couldn't throw a whiskey bottle out of a hotel window at a meeting of aeronautical engineers without hitting some fellow who had ideas on jet propulsion." Indeed, in August of 1939, just days before the first flight of the He 178, he had submitted a report to General Arnold's office (Air Corps Materiel Division Engineering Section Memorandum Report 50-461-351) recommending an extensive transonic research program and suggesting that gas turbine or rocket propulsion systems would have to be developed to support such an effort because of compressibility limitations on prop-driven aircraft at high speeds. His recommendations were apparently ignored by Arnold's staff.

In hindsight, it may seem remarkable that Kotcher's bold recommendations should have been greeted with so little interest. However, at the time, Arnold and his staff were riveted on the immediate problem of building an air force to fight an imminent war and that meant focusing on the accelerated production of aircraft and related systems already under development. Indeed, by June of 1940, Arnold informed his staff that the Army was only interested in airplanes that could be delivered "within the next 6 months or a year, certainly not more than two years hence" and that all research and development activity would be curtailed in order to insure timely production of existing designs. Within this context, proposals to develop radical new technologies were relegated to the back burner. This was particularly true with regard to something as exotic as jet propulsion because the assumption in the United States, as it had been in England, was that its development would, at best, be a very long-term proposition.

Military interest in exploring the feasibility of the concept in this country actually dated back to the early 1920s. In 1922, the Air Service Engineering Division at McCook Field, Ohio, asked the Bureau of Standards to investigate the practicality of reaction propulsion. While conducting this study, Edward Buckingham based his calculations on a compressor driven by a reciprocating engine and did not consider any form of gas turbine. In his report, published by the NACA in 1923, he concluded: "propulsion by the reaction of a simple jet cannot compete, in any respect, with airscrew propulsion at such flying speeds as are now prospect." Fuel consumption at those speeds, for example, would be about four times higher. That was true, in 1922, when the airspeeds envisioned were only about 250 mph. But he went even further, concluding that there was "no prospect whatsoever that jet propulsion...will ever be of practical value, even for military purposes." Unfortunately, his conclusions were based upon a number of erroneous assumptions. Because he failed to consider the possibility that aircraft might someday be able to fly at speeds well in excess of 250 mph, he failed to consider the possibility that fuel efficiency might significantly improve at higher speeds. Like his counterparts elsewhere, he also assumed that compressors would necessarily have to be huge and heavy devices similar to those then used for industrial purposes. At the Langley Memorial Aeronautical Laboratory (LMAL), NACA researchers would accept Buckingham's conclusions as their own and his erroneous assumptions would cast a pall over serious research into the subject for more than a decade. Thus, even the very few research studies that were conducted by the NACA and the Bureau of Standards during this period merely confirmed Buckingham's conclusions because they were all largely based on those same assumptions.

Indeed, the piston engine-prop combination was such a given that the NACA virtually abandoned the field of propulsion research to industry and the military services and opted, instead, to commit the bulk of its resources to the study of aerodynamics. Under this circumstance, historian James R. Hansen has noted: "The LMAL had but one comparatively small research division devoted to engine research, but the outlook of its members was 'slaved so strongly to the piston engine because of its low fuel consumption that serious attention to jet propulsion was ruled out.'"

The aero-engine industry shared this assumption and was certainly not about to shift toward any radical new concepts. Like their counterparts elsewhere, Wright Aeronautical and Pratt & Whitney poured enormous resources into progressive refinements of basically unchanging air-cooled designs. Indeed, between 1926 and 1939, the whole procurement system under which they were forced to operate actually discouraged radical innovation. There were virtually no military contracts issued exclusively for experimental research for its own sake. All such costs had to be recouped—or amortized—in subsequent production contracts. Radical innovations could well require years of trial-and-error development effort before they *might* prove worthy of mass production and thus there was little incentive to pursue such a course. The engine manufacturers had a vested interest in the status quo and seemed to be largely unaware of—or unconcerned about—the implications of the pending revolution in high-speed aerodynamics until very late in the game. Wright Aeronautical conducted no studies of its own on gas turbines and it was only in 1941, after it had somehow obtained intelligence on the success of Whittle's experiments, that the company attempted to obtain a license for the manufacture of his engine in this country. Prior to 1940, some individuals at Pratt & Whitney had briefly examined the potential of gas turbines and, indeed, by May of 1941, the company was actually conducting some very preliminary tests on components for a compound engine (gas turbine wheel geared to the crankshaft of a piston engine) that had been designed by Andrew Kalitinksy of M.I.T. This was an extremely low priority effort, however, and nothing ever became of it.

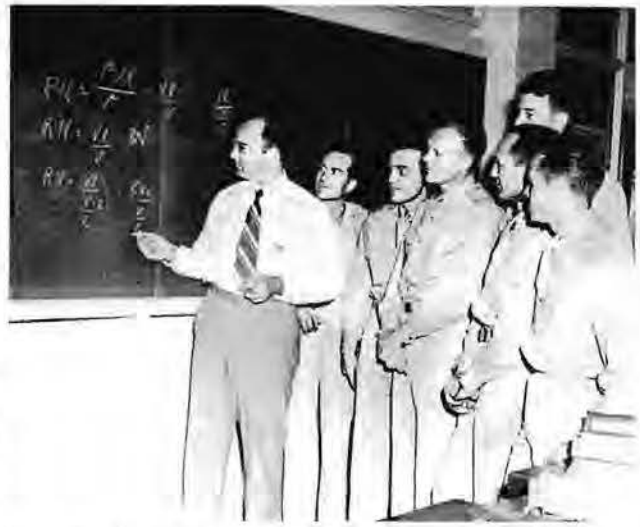
The major engine manufacturers' priorities were well established and it was certainly by design that, when the NACA Special Committee on Jet Propulsion was formed in the spring of 1941, General Arnold expressly prohibited their participation. He wanted them to concentrate on the production of conventional engines to meet the crisis at hand and, backed by advice from Vannevar Bush and the chief of the Navy's Bureau of Aeronautics, he also suspected that they would be resistant to any radical new departures. And, despite Pratt & Whitney's subsequent claim that it was late in getting into turbojet development only because of Arnold's decision, company officials apparently expressed very little interest in entering the field even after they were invited to participate. Lieutenant General Donald L. Putt, then a project officer at Wright Field, later recalled sitting in on a conference with Pratt & Whitney personnel during which Brigadier General Franklin O. Carroll, chief of the Engineering Division, tried to encourage them to get involved in developing turbojets. "They were very firm in their conviction that the turbine engine would never be much of a threat," he recalled. "The piston engine was going to be with us forever; it was the way to go. There might be some place for a turboprop but for a straight jet, forget it."

On the military side, the Power Plant Branch at Wright Field was certainly not prepared to lead the way. First of all, in the 1920s, the NACA had very forcefully staked its claim as *the* institution responsible for fundamental aeronautical research in the U.S. and it jealously guarded its position throughout the 30s. The Air Corps, by law, was to limit its activities to *applied* research and, throughout the 30s, officials at Wright Field were loath to invade the NACA's turf for fear of arousing Congress' ire. As far as Air Corps leaders were concerned, it was the NACA's job to conduct fundamental research and keep up with the latest scientific developments and, always strapped for funds throughout the 30s, they were quite willing to defer to the NACA in this regard.

Just because the NACA had abandoned propulsion research to industry and the military did not mean that anybody ever directed the Air Corps to fill the void or undertake fundamental research of any kind. The military's job was to conduct applied research and thus, as historian I.B. Holley has observed, the personnel of the Power Plant Branch at Wright Field "had their goals rather clearly laid out for them: they were to strive for better engines, meaning more horsepower at less weight. They were to minimize fuel consumption, to reduce frontal area in order to reduce drag, and to achieve maximum reliability and durability."

Moreover, even if given the job, there were a number of other circumstances that militated against *any* kind of serious research effort. General Jimmy Doolittle once observed that research and development (R&D) is like virtue; everyone believes in it but no one wants to sacrifice for it. This was *certainly* true for the Army Air Corps during the interwar years. Throughout the period, its entire R&D budget generally hovered between $2-4 million (and, most often, at the lower end of the scale). More tellingly, between 1926 and 1939, R&D expenditures as a percentage of the total Air Corps budget plummeted from 16 to just *five* percent. Out of these paltry sums, no more than 30 percent was ever dedicated to propulsion systems and virtually none was directed toward experimental research of any kind because the emphasis at Wright Field was on the procurement of systems destined for the operational inventory. Indeed, the very structure of the Materiel Division mandated this kind of emphasis. With the establishment of the Air Corps in 1926, both R&D and procurement were brought together under the new Materiel Division at Wright Field. While the merger improved coordination between the two areas, it had a number of unintended side effects. Most important, the requirements of the procurement side of the house absorbed an ever greater percentage of the available technical manpower, facilities and other resources in support of routine specification compliance testing of aircraft and systems submitted by manufacturers. The practical consequence of this, as I.B. Holley has noted, was that experimental research fell by the wayside.

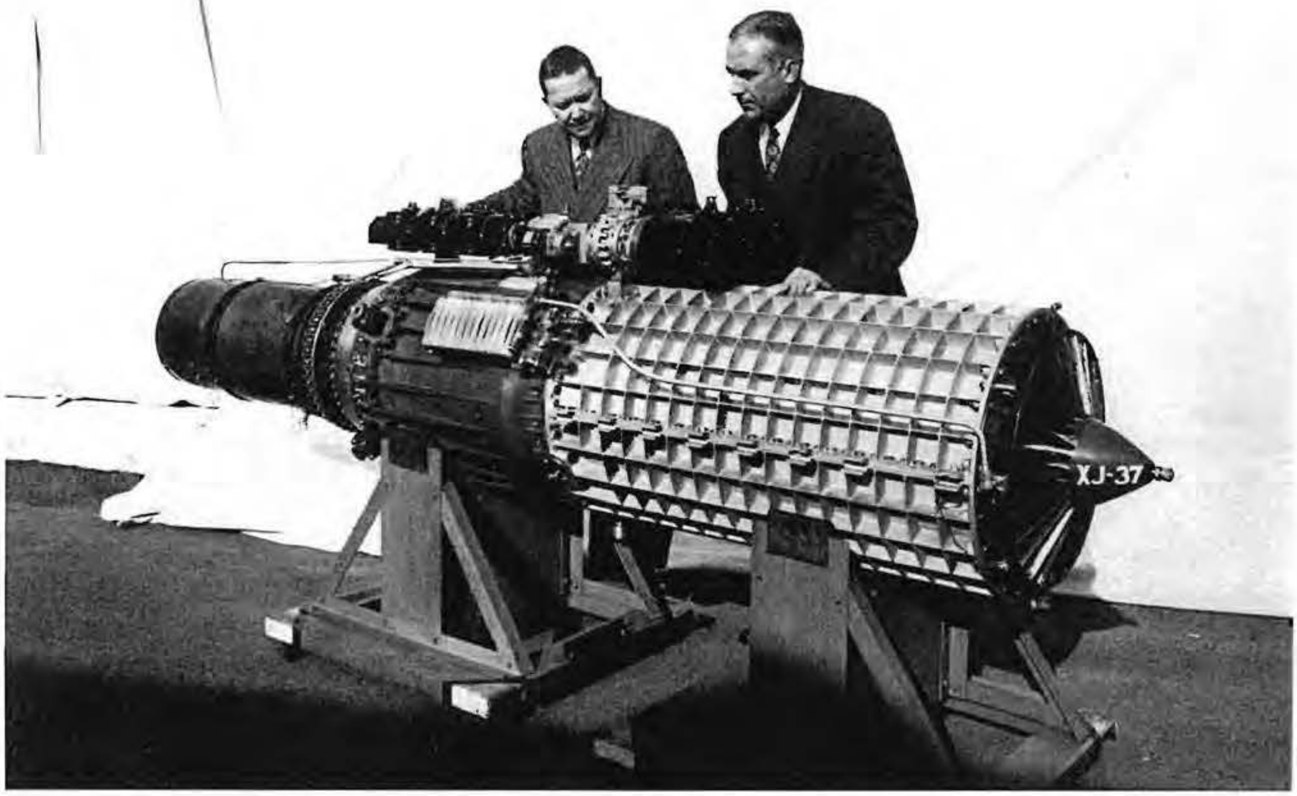
Inadequate funding also translated into serious deficiencies both in the number and quality of technical personnel assigned. The Materiel Division suffered from a serious shortfall in engineering manpower throughout the 1930s. A single project officer assisted by a single civilian engineer, for example, was typically responsible for the development of all pursuit or bombardment or trainer aircraft. Moreover, the scientific and technical competence of the staff was well below par. Lieutenant General Laurence C. "Bill" Craigie served several tours at Wright Field during the 30s and 40s and he later recalled that, when he arrived in late 1934, no more than a dozen individuals, out of 1,100 personnel, could be considered as "real scientists" and there were fewer still who, like Kotcher, could cross disciplines. Five years later, an investigating board reported "an appalling lack of qualified personnel...particularly in key positions." The most serious deficiency was among the officers, only a fraction of whom had any of the relevant scientific and technical training which had, by then, become so necessary to cope with the burgeoning complexity of aviation technology. A handful of the most qualified were selected each year to attend the Air Corps Engineering School. The year-long curriculum, however, provided little more than a one- or two-week orientation into the activities of each of the labs and test organizations at Wright Field. The much larger civilian staff tended to be a cut above the officers. However, low pay and limited promotion potential generally drove the best among them to higher-paying jobs in industry. Thus there were, at best, never more than a few individuals at Wright Field who were sensitive to the growing interaction between fundamental and applied research and fewer, still, who were capable of crossing disciplines and perceiving the sudden convergence of thermodynamic with aerodynamic principles. The upshot of all of this was not only that the Air Corps' principal R&D organization was ill equipped to conduct serious research but also that it put the Air Corps at a tremendous disadvantage in attempting to deal with the larger scientific and technical community from which it might have benefited.



***Ezra Kotcher teaching one of his classes at the Air Corps Engineering School at Wright Field in 1940. Tall student (partially obscured) at right is Lt. Bernard A. Schriever, one of many Kotcher students who went on to make major contributions to American air and space power.***

All of this made for an almost classic "who's minding the store?" scenario. Industry depended on the Air Corps for direction in terms of requirements and the Air Corps, in turn, depended on the NACA for fundamental research; because the piston engine appeared to be such a given, the military never called upon the NACA to investigate radical new forms of propulsion and the NACA, in turn, virtually abandoned the field, leaving it up to industry and the military; but industry did not have the incentive to take on the job and the military did not have the expertise to look in new directions or even to direct either industry or the NACA to do so.

By 1940, as noted above, Pratt & Whitney was doing some very limited, component-level work on a compound engine. The NACA was actually conducting some useful research on compressors and one of its most brilliant aerodynamicists, Eastman Jacobs, was preparing to demonstrate the feasibility of a ducted fan concept first conceived by Italian Secondo Campini in 1930. If all went well, it was conceivable that this system *might* be ready for inflight testing by 1943. In 1936, someone in the Engineering Section at Wright Field had produced a report titled "The Gas Turbine as a Prime Mover for Aircraft" but, like Kotcher's report three years later, it did not generate enough interest to stimulate any kind of major research program. In addition to looking at jet-assisted (really rocket) take off, the use of piston engine exhaust to provide supplementary jet thrust, and reviewing (and typically




*Lockheed's Hall Hibbard with XJ37 engine designer Nathan Price at right.*


*Hall Hibbard holding a model of the L-133.*

rejecting) proposals for all manner of reaction propulsion systems, the Power Plant Laboratory had launched a modest program in 1938 which was aimed at developing a successful compound engine by 1943. There was no sense of urgency in any of the above-mentioned efforts and none of them *ever* evolved into successful propulsion systems.

## *American Visionaries*

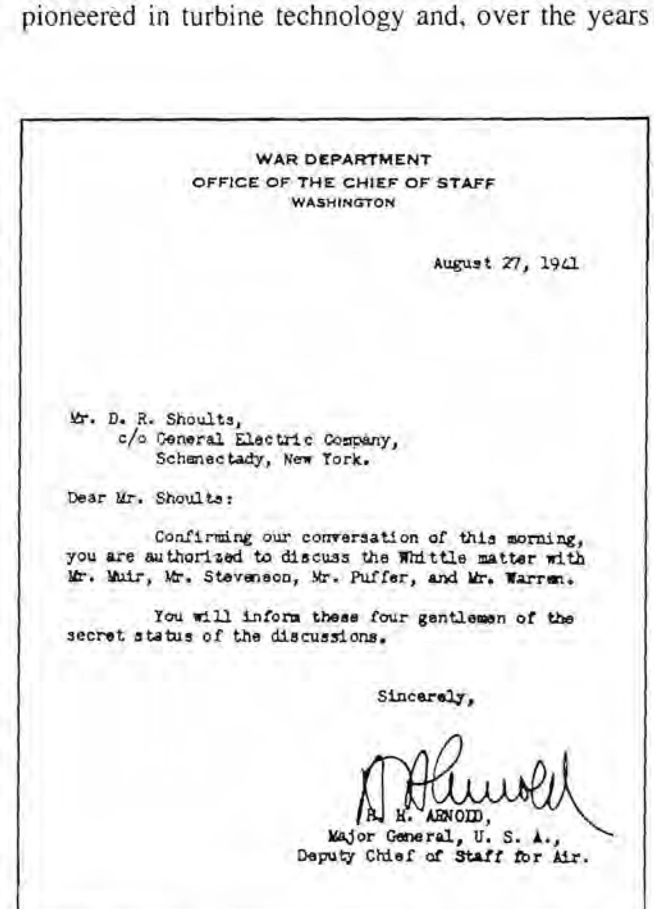
As in Europe, interestingly enough, the only projects underway which were headed in the right direction all had their genesis outside of the aero-propulsion establishment. In 1936, engineers at General Electric started publishing internal research bulletins and reports on the feasibility of employing gas turbines as a primary source of power to drive propellers and, by 1939, Dale Streid was writing optimistically about "propulsion by means of a jet reaction." These studies were ongoing right up to April of 1941 when G.E. (Schenectady Division), Allis Chalmers and Westinghouse were invited to join Dr. Durand's Special Committee on Jet Propulsion (each of these turbine manufacturers ultimately commenced development of their own turbojet designs).

Meanwhile, Jack Northrop appeared to have stolen a march on everyone. On the basis of design studies initiated in 1939, he became convinced of the superiority of a gas turbine over the conventional piston engine for driving propellers. After commencing initial development of a turboprop engine—which he called the Turbodyne—with his own resources, he approached the Army and Navy for support. Neither showed any interest until June of 1941 when they issued a joint-contract to pursue development of what was subsequently designated the XT37. Like all of the early turboprops, the project was ambitious in concept and excruciatingly slow in development. Three test engines were finally built in 1947 and, though never flight tested, one of them eventually delivered an impressive 7,500 hp during bench tests before the project was canceled in 1949. By then, Northrop's ingenious engine had been overtaken by the turbojet.

By far the most interesting development was taking place at Lockheed. Since the mid-30s, Clarence L. "Kelly" Johnson had been well aware of the theoretical implications of compressibility phenomena and, by 1939, he and Hall Hibbard had decided to do away with the prop altogether! Unlike so many others in this country, they *were* capable of perceiving the sudden convergence of aerodynamic with thermodynamic principles and they asked Nathan Price to design a pure turbojet that would power a truly radical interceptor at speeds never before envisioned in this country. Initial development of the engine, designated L-1000, got underway in 1940 and, though his initial concepts were far too complex to be practicable, Price ultimately came up with a truly remarkable design—a high-compression-ratio, twin-spool, axial-flow turbojet promising a then extraordinary 5,000 pounds of thrust at takeoff. Meanwhile, Kelly Johnson led a small design team that came up with the L-133, an equally remarkable twin-engine, stainless steel airplane, featuring thin wings and canard surfaces, and projected to attain a whopping 620 mph at 20,000 feet (and nearly that speed at 50,000 feet)! Much to Johnson's chagrin, officials at Wright Field considered the radical airplane to be a far too risky venture when he delivered the design and technical data in March of 1942. The engine, however, showed enough promise for Lockheed to win a contract for further development of what became known as the XJ37. The engine never got beyond the development stage. Kelly Johnson's knowledgeable interest in jet-propelled airplanes, however, had made what would prove to be a *very* important impression on the Experimental Engineering Section at Wright Field.

## *Hap Enlists General Electric and Bell*

Like so many among the top Air Corps leadership, Hap Arnold had never been technically inclined and he was probably unaware of most of these developments. But, when confronted with the palpable evidence of Whittle's achievement, he immediately grasped its implications and acted quickly to expedite America's late entry into the jet age. After promising the British he would clamp the tightest security precautions on the project, he managed to gain permission to build the Whittle engine in the U.S. by late summer 1941. Next, he had to decide who would produce it. Because of their resistance to change and because they were already heavily committed to supporting the immediate build-up of American air power, the major engine manufactures were excluded. Brigadier General Oliver P. Echols, chief of the Materiel Division of the recently redesignated Army Air Forces (AAF), and his assistant, Lieutenant Colonel Benjamin W. Chidlaw, recommended General Electric because they were well aware that the company had pioneered in turbine technology and, over the years



WAR DEPARTMENT
OFFICE OF THE CHIEF OF STAFF
WASHINGTON

August 27, 1941

Mr. D. R. Shoults,
c/o General Electric Company,
Schenectady, New York.

Dear Mr. Shoults:

Confirming our conversation of this morning, you are authorized to discuss the Whittle matter with Mr. Muir, Mr. Stevenson, Mr. Puffer, and Mr. Warren.

You will inform these four gentlemen of the secret status of the discussions.

Sincerely,

H. H. ARNOLD,
Major General, U. S. A.,
Deputy Chief of Staff for Air.

***Letter from General Arnold to G.E.'s D. Roy Shoults granting him permission to discuss the jet engine project with senior management at the company.***

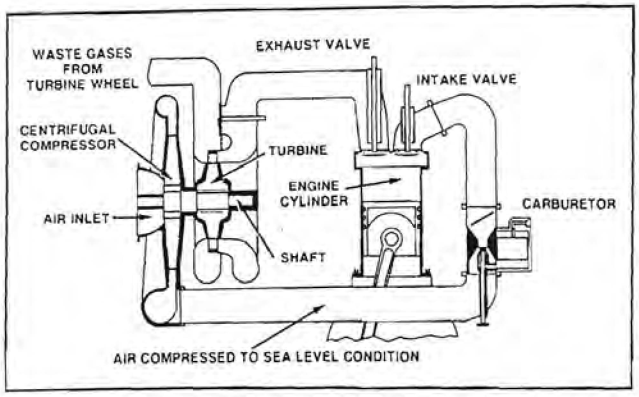



*Figure 2 - Cutaway image of an early turbosupercharger.*

since World War I, it had perfected the development of turbosuperchargers which permitted piston-engined airplanes to climb to otherwise impossible altitudes.

Indeed, turbosupercharging was based on many of the same principles as jet propulsion (Figure 2): at high altitudes, the thin air was compressed to sea-level conditions by a centrifugal compressor and directed through a carburetor, where fuel was added, and then through an intake valve into a piston cylinder where it was ignited; then, passing through an exhaust valve, the exhaust gases were channeled through a turbine wheel which, in turn, drove the compressor. G.E.'s extensive work with the turbosupercharger and, most important, the high-temperature alloys necessary to build them made it the logical choice to take the next step and thus, in a meeting in Arnold's office on September 4, 1941, G.E. was offered a contract to reproduce the 1,650-pound thrust Whittle W.2B engine.

Arnold's choice to design and build the airframe was almost as easy. His concerns about disrupting top-priority existing development and production programs were a major factor in this decision and, based again on advice from Echols and Chidlaw, he selected a company that certainly was not overburdened with such work. With innovative (though not very successful) designs, such as the YFM-1 "Airacuda" and the P-39 "Airacobra," the Bell Aircraft Corporation's team of designers had at least established a reputation for inventiveness and Larry Bell's own seemingly boundless drive, Arnold and his staff believed, would guarantee that any project would be completed on time and up to expectations.


*Larry Bell with Wright Field test pilot Captain Perry Ritchie in front of a P-39 at the Bell plant in 1942.*

Bell agreed to tackle the job on September 5, 1941. The next day, he selected a small group of six engineers and assigned them the task of creating a preliminary design for the aircraft. Working with little more than a small free-hand sketch of the engine, the "Secret Six," as they were called, prepared a design proposal and a 1/20th scale model within the span of just two weeks. Arnold gave his approval and a fixed fee contract for $1,644,431 was finalized on October 3. It stipulated that the first of three "twin-engine, single-place interceptor pursuit models," with a projected combat ceiling of 46,000 feet and a top speed of nearly 500 mph, should be delivered within just eight months. A similar $630,000 contract was negotiated with General Electric for 15 engines with the initial pair of flight-ready engines, each providing 1,650 pounds of thrust, to be available for installation on the first aircraft. Remarkably, and though Arnold doubted that it was possible, his staff was hoping that an engine-airframe combination could be designed and developed which could be rapidly transitioned into a combat-worthy production fighter. This goal was incredibly ambitious and the schedule was tight, to say the least.

Chidlaw was selected by Arnold and Echols to provide overall direction for the program (subsequently designated Project No. MX-397). He, in turn, chose Majors Ralph Swofford, from the Engineering Division's Experimental Aircraft Projects Section at Wright Field, and Don Keirn, from the Power Plant Lab, to serve as airframe and engine project officers, respectively (within months Chidlaw was promoted to the rank of brigadier general and Swofford and Keirn each to the rank of full colonel).

Ralph Swofford and Don Keirn would each shoulder a tremendous amount of responsibility in the months ahead. In those days, a project office was responsible for all of the many functions later handled by system program offices staffed with hundreds of personnel. Due to the "super secret" nature of this program at its outset, no more than a dozen people at Wright Field had any knowledge of its existence. In Swofford's and Keirn's case, each was intimately involved in the design and development process on a daily basis and each had enormous authority. Every design change required their personal approval. And, indeed, during the early months of the flight test program, long before official AAF flight tests got underway, each would also find himself serving as a *de facto* test pilot. After every significant modification to one of the prototype airframes, for example, Swofford would always fly the airplane before approving or disapproving it for inclusion in the production design. Small wonder that after he had retired as a two-star general years later, Don Keirn recalled that he had been entrusted with *far more* authority as a major during the hectic early months of this program than he would ever later enjoy as a general officer.

***From l-r: Brig. Gen. Ben Chidlaw, Col. Don Keirn and Col. Ralph Swofford.***

## *Working in Haste, Secrecy and Solitude: The Design and Development of the XP-59A and the I-A Engine*

In a fashion that would become a hallmark of the American aviation industry during the war years, a small design team hastily set to work at Bell with a profound sense of urgency and only a few rough drawings of the proposed engine in hand. Tasked with designing an entirely new type of airplane, they were further required to come up with a design that would also be suitable for combat service. Beyond the single stipulation to wrap an airframe around a pair of the new power plants, they were free to improvise...but they had to work quickly and without the benefit of any outside advice or assistance. Because of the "Top Secret" security restrictions imposed by Arnold, for example, they were not permitted to make use of the NACA's full-scale wind tunnel facilities and were forced, instead, to rely

*XP-59 project meeting at Bell's Buffalo facility in 1942. From l-r: (seated) Bell chief engineer Harland Poyer and Col. Ralph Swofford, (standing) Bell project engineers Robert A. Wolf and Ed Rhodes, AAF project engineer Capt. Ezra Kotcher and Bell chief test pilot Bob Stanley.*

on very imperfect data from the five-foot, low-speed tunnel at Wright Field. By mid-November, General Echols was already pleading with Arnold to rescind this restriction because he could already foresee boundary-layer problems with the engine inlets unless the design team could get some hard data on high-speed flow conditions. Arnold, however, was adamant and this decision would, indeed, result in some serious miscalculations that would severely limit the performance of the airplane. Nevertheless, working in haste, the design team completed its work by early January 1942 and a small, select crew of Bell workers began to build the airplane, literally by hand, on the closely guarded second floor of a Ford agency in Buffalo, New York. In the interests of secrecy, the aircraft had been given the designation XP-59A, a designation originally intended for a proposed Bell pusher-prop fighter that never got beyond the mock-up stage.

Equally stringent security precautions were in force at G.E's Lynn River facility, in Massachusetts, where another small team headed by Donald F. "Truly" Warner labored, non-stop, on a design that, again for security purposes, had been designated "Type I-A supercharger." With the benefit of Whittle's W.1X engine, which had been used in the taxi tests of the E.28/39 and on which they were able to run tests, and working from reportedly incomplete drawings of his W.2B design, they made some minor modifications to the diffuser, combustors and bearings of the British design and built a prototype.

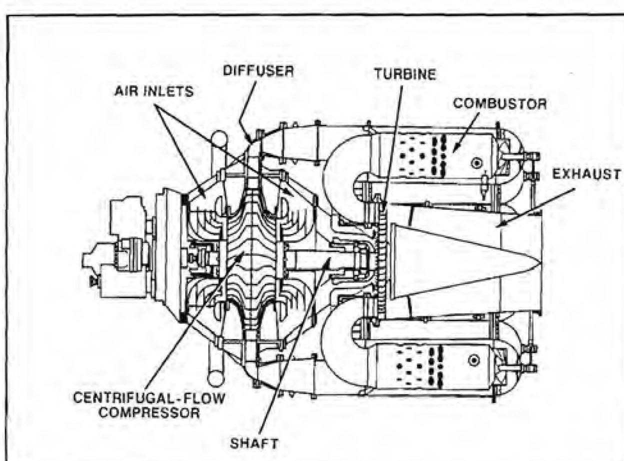
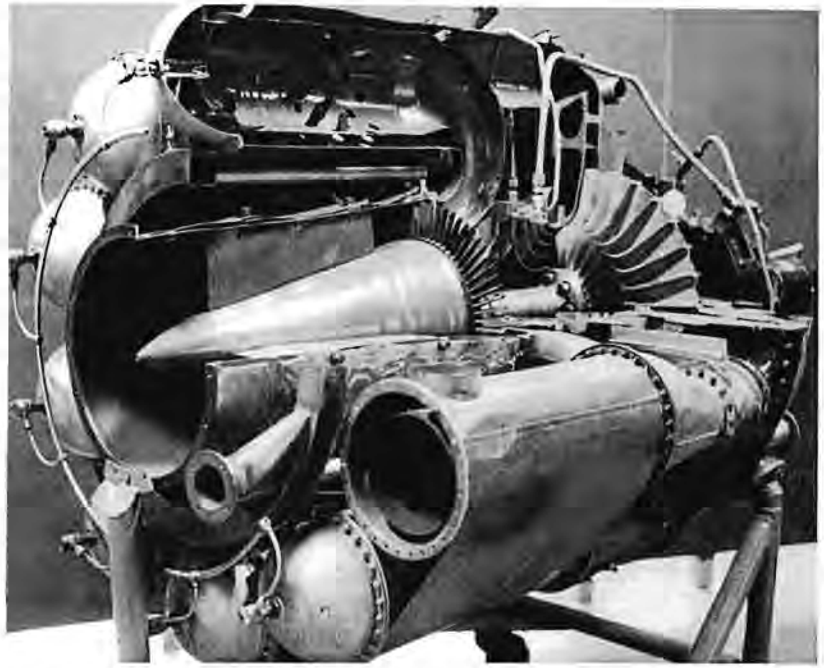



*Figure 3 - Cutaway image of the General Electric I-A engine.*

On March 18, just 5 1/2 months after taking on the job, they wheeled the engine into a test cell—aptly named "Fort Knox"—for its first test run. However, the engine stalled and this attempt was unsuccessful. But, exactly one month later, on April 18, Truly Warner once again advanced the throttle and, this time, the engine successfully roared to life. With the push of a hand, he had finally lit the flame of the turbojet revolution in America.

The G.E. Type I-A engine was a centrifugal, reverse-flow turbojet that represented a quantum advance over Frank Whittle's original 1930 patent design (Figure 3): it featured inlets, configured with guide vanes, which directed air into a single-stage, double-sided impeller—a centrifugal compressor—that roughly tripled the air's pressure as it passed through the diffuser and into any of ten reverse-flow combustion chambers where it was ignited and the intensely hot, expanding gases raced through the turbine—which drove the compressor—and exited through a single exhaust nozzle at high speed to produce thrust.

The G.E. team proceeded with what would become a lengthy and sometimes painful development process. The thrust performance of the test unit, for example, never came close to matching the British design predictions for the W.2B (it was not until early 1943 that they would learn that the thrust curves they were using were different than those employed by the British). When Wing Commander Whittle arrived in June 1942, he found Truly Warner and his team struggling with excessive turbine inlet temperatures, cracked turbine blades, bearing failures, excessive carbon formation in the flame tubes due to poor combustion efficiency and a host of other problems. Warner had found it necessary to experiment with a variety of different diffuser, combustor and turbine bucket designs and materials and



*Above: Cutaway section of the I-A engine showing features such as the compressor, diffuser, air inlet guide vanes, combustor and turbine. Below: Donald F. "Truly" Warner (at center with glasses and cigar) hosts Frank Whittle (third from right) and the first British delegation to see the I-A engine, June 1942.*

Whittle was quick to caution that, due to the decision to locate the engine nacelles alongside the airplane's fuselage (as opposed to using the wing mounted pods that would be employed on the Meteor), boundary layer problems would severely reduce ram air efficiency. Despite all of these problems, Chidlaw reported to Arnold's office that "Bell and G.E. have both done a bang-up job in rushing this thing through" and that the XP-59A effort was "well ahead" of Britain's Meteor project which had enjoyed a one-year head start. He attributed this lead principally to

*XP-59A offloaded from boxcars at Muroc test site.*

the fact that General Electric's years of experience with turbosuperchargers had put the U.S. well ahead in the development of high-strength, heat-resistant alloys.

Nevertheless, Bell's completion of the first airframe was held up by General Electric's inability to deliver flight-rated engines until early August and by then, it was already quite apparent that the I-A power plants would never be able to deliver more than 1,250 pounds of thrust. Indeed, Warner had already proposed major modifications to the original design that would result in an I-16 unit capable of producing the desired 1,650 pounds of thrust.

## A Place Called "Muroc"

Meanwhile, as G.E. proceeded with tests and the Bell team assembled the first airplane during the spring and summer of 1942, a continent away, Major Joe Dodd launched the construction of a small Materiel Center Test Site on the northern edge of an enormous dry lake at an out-of-the-way place called Muroc on California's high desert. Eight miles to the south, Muroc Army Air Base served as a training base for fighter and bomber crews preparing for overseas deployment and this would remain the principal activity at the high desert installation throughout the war years. The area along the north shore of the lakebed had already been set aside by General Arnold as a place to test "special weapons" in late 1941.

The jet project was so secret that there was never any question of testing the airplane at Wright Field, the Bell facility at Niagara Falls Airport or anywhere else in the congested northeastern United States. After surveying potential sites all over the west, General Chidlaw and Colonel Swofford finally settled on Muroc, in April of 1942, because of its extremely remote location, the superb year-round flying weather, the proximity of a railhead and the availability of the vast, 44-square mile expanse of Rogers Dry Lake. It was obvious to them that the immense, concrete-like lakebed would provide an ideal natural landing field from which to explore all of the unknown characteristics of the new jet aircraft.

Since the real estate officially belonged to the Fourth Air Force, Swofford had to arrange for a formal transfer of all territory north of the Santa Fe railroad tracks that then intersected the lakebed. It was clear from the outset that he foresaw the long-term potential of the site. In his draft of the official notice of transfer, dated June 27, 1942, he wrote: "It is intended that this base be of a permanent nature and be available to the Materiel Center [at Wright Field] for all types of testing which require an especially large operating area or an unusual degree of secrecy."

It might have had tremendous potential but, when Bell chief test pilot Bob Stanley arrived at the test base in August, he found what could best be described as very "Spartan-like" accommodations: an unfinished portable hangar, a water tower and a wooden military barracks and mess hall that Bell, G.E. and AAF personnel quickly named the "Desert Rat Hotel." These three totally unimpressive structures represented the humble beginnings of what would one day become well known around the world as the U.S. Air Force Flight Test Center.

## *The Jet Takes Flight*

On September 19, the engines and crated pieces of the airplane were off-loaded from boxcars after a long, cross-country journey on what its weary G.E. escorts mockingly called the "Red Ball Express." Working, quite literally, day and night, Bell and G.E. personnel set about to reassemble the craft. They completed the job within a week and, on September 26, the XP-59A rolled out from the hangar for the first time. In many regards, the mid-wing fighter prototype appeared to be a fairly conventional design. But there were certain features that caught the eye. Fully loaded, it weighed just under 10,000 pounds and, with a wing loading of 25 lbs/sq. ft., its immense wings (400 square feet) appeared to be optimized for high-altitude flight. The tail section swept upward very noticeably and the craft rested extremely low to the ground on its tricycle landing gear. And then, of course, there was no prop and tucked beneath the wings, along the fuselage, were a pair of nacelles housing the I-A engines.

Those engines roared to life on the aircraft for the first time that day and, by September 30, just four days later, Bob Stanley and the airplane were primed for its initial taxi tests. After completing some low-speed trials, he proceeded to a series of high-speed runs in order to get a feel for the controls. On a couple of these runs, late in the day, the wheels of the airplane actually lifted a couple of feet off the lakebed. Stanley, a brilliant engineer and a relentlessly hard-driving personality who seldom counted patience among his virtues, was all for making the first flight then and there. Larry Bell, however, overruled him because high-ranking official observers—such as Dr. Durand from the NACA and Colonel Laurence C. "Bill" Craigie, chief of the Experimental Aircraft Section at Wright Field—were not scheduled to arrive for two days.

On the following day, October 1, Stanley made four additional "high-speed taxis," during the first of which the aircraft lifted off and soared some 25 feet above the surface of the lakebed. And, on subsequent runs, it climbed to as high as a hundred feet. *Un*officially, the XP-59A had *unquestionably* flown. But the brass had not been there to witness the event so, "officially," it had not really happened.

*Top: Bell and General Electric crews worked day and night to reassemble the XP-59A at Muroc. Middle: Bell test pilot Bob Stanley (in cockpit) ran up the engines on the aircraft for the first time on September 26. Bottom: Bob Stanley in the cockpit of the XP-59A shortly before takeoff on October 1, 1942.*

Finally, on October 2, the brass *was* on hand. At about 1 p.m., Stanley advanced the throttles, released the brakes and, slowly at first, the aircraft moved across the hard-baked clay of the lakebed. After what seemed like an unusually long takeoff roll, the XP-59A's wheels finally left the ground and, remarkably, just one year—almost to the day—after commencing the project, the United States had finally and officially entered the jet age. General Electric's Ted Rogers reported what he called a "strange feeling" as he witnessed the flight: "dead silence as it passed directly overhead,...then a low rumbling roar, like a blowtorch...and it was gone, leaving a smell of kerosene in the air." The smell of kerosene resulted from fuel leaking from a malfunctioning vent just inboard of the right aileron.

Others apparently *also* saw the flight...and what appeared to be a trail of smoke coming from the airplane. Joe Dodd got a call from the training base across the lakebed. An excited voice asked if he needed a fire truck. "I'm quite sure we can handle it," he calmly replied. The visible "smoke" in the jet's exhaust was actually the product of incomplete combustion of the kerosene fuel.

General Electric had prudently imposed several restrictions on the engines for the initial flights. Stanley was instructed, for example, not to exceed 15,000 rpm (maximum was 16,500) and the engines were each limited to about 850 pounds of thrust during what he described as a "leisurely" climb to 6,000 feet. The engines were also limited to just three hours of running time before they would have to be pulled for inspection and overhaul. Thus, after Stanley completed his second flight that day up to about 10,000 feet, he turned to Colonel Craigie and said: "Bill, we've only got about 45 minutes left on the engines. How'd you like to take it up?" As Craigie later recalled, "he didn't have to ask me twice." Although he had been on hand only to serve as the AAF's official observer, he climbed into the cockpit and went up for a 20-minute flight. After he landed, he reported, as virtually all who followed him would: "I didn't get very high. I didn't go very fast. The most vivid impression I received, after a very long takeoff run, occurred at the moment we broke contact with the ground—it was so *quiet*!" Thus it was quite by happenstance that Colonel Craigie became America's first military jet pilot. As he was to recall many times in later years: "Things were a *lot* less formal in those days."

***Among those on hand to witness the first "official" flight of the XP-59A were Bell chief engineer Harland M. "Hi" Poyer (3rd from left), G.E.'s Donald F. "Truly" Warner and Ed Tritle (5th and 6th from the left), as well as Dr. William F. Durand (2nd from the right), the head of the NACA's Special Committee on Jet Propulsion and then the only representative from the NACA who had been briefed into the program.***

*Bob Stanley (left) and Col. Bill Craigie (right) following their flights in the XP-59A on October 2.*

*The full Bell, G.E. and AAF team after the first "official" flight on October 2. Bob Stanley (at left) and Ed Rhodes (at right) were seated on the wing. Among those in the middle row: Larry Bell (2nd from left), Harlan Poyer and G.E.'s D. Roy Shoults (4th and 5th from left), and Col. Bill Craigie (9th from left). Major Joe Dodd, who served as the test site officer-in-charge, is at the far right of the front row.*

*The XP-59A during one of its initial flights over the bombing and gunnery range at Muroc.*

*Bell's Don Thomson (at left) and Clifford Moore manning the "mission control center." Note water tower, uncompleted hangar and "Desert Rat Hotel" barracks in the background.*

## *Testing America's First Jet*

Less formal, indeed! The differences between flight testing, then and now, are certainly well illustrated by the XP-59A program.

There were no safety chase airplanes that day and the most important instrumentation—at least during the initial flights—remained the seat of the pilot's pants. It may not have been too scientific but, by latter-day standards, it was relatively inexpensive and it afforded a means of real-time data acquisition that was *always* certain to yield immediate analyses of any problems. The aircraft was ultimately instrumented to cover 20-30 different parameters but the instrumentation was often primitive, to say the least. Control stick forces, for example, were measured with a modified fish scale and engine thrust was originally measured by means of an industrial spring scale attached to the landing gear and anchored to the ground. Nobody had ever tested a jet airplane before and the lack of a satisfactory means of measuring thrust on the aircraft—especially in flight—would severely hamper flight test efforts throughout the P-59 program by making it impossible, for example, to correlate airplane drag to net engine thrust.

There was no telemetry. Indeed, the entire "mission control center" consisted of a two-way radio and an old voice recorder that were set up on the lakebed adjacent to the hangar. A couple of the test aircraft were eventually modified to provide open-cockpit observation seats so engineers or technicians could sit in front of the pilot and read and record the data. Probably the only jet-powered airplanes ever to offer such exhilarating aircrew accommodations, these two airplanes provided a lot of ground crew personnel and VIPs with their first, no doubt thrill-packed, exposure to jet flight (photopanels were subsequently installed in most of the test aircraft).

***D. Roy Shoults (seated) checking the spring scale that measured installed engine thrust. Bob Stanley (at left) and Bell onsite test manager Ed Rhodes (foreground) look on.***

***Members of the ground crew, like Jack Russell, got their first jet ride in an open cockpit. Russell later served as Chuck Yeager's crew chief for the X-1.***

***Doorbell mechanism on the instrument panel can be seen in the upper right corner of this image. The "cyl temp" gauges (at bottom) were actually used to display engine bearing temperatures.***

It was an age when, without the benefit of vast technical resources, improvisation and old-fashioned mother wit still ruled supreme. Sitting in the cockpit, the XP-59A *did* seem incredibly quiet and, unlike piston-engined airplanes, its ride was unbelievably smooth. In fact, the engines ran so smoothly that the cockpit instrumentation tended to stick because of the lack of vibration. What to do? A resourceful Bell technician mounted a doorbell mechanism, which functioned as a vibrator, on the instrument panel and solved the problem for less than $2.00.

Sometimes, improvisation resulted in practices that might best be described as questionable. The P-59 was the first fighter aircraft in this country to be designed with a fully pressurized cockpit. The state of the art in the early 40s was far from advanced and there were chronic problems with the pressure regulators and the cabin seals. The seals, in particular, had to be constantly replaced and tested. No one had ever previously had to test for cockpit pressurization and there were certainly no technical manuals around to provide guidance. While it required what could be considered hazardous duty, the method devised by the test team proved to be very simple and quite effective. Whenever they had to test the seals, they had Angus McEachern, one of G.E.'s technicians, get in the cockpit. Then they closed the canopy, pumped compressed air into the cockpit, and checked for leaks as McEachern sat there...puffing away furiously on a cigar!

***XP-59A towed on the ramp at the Materiel Center test base with dummy wooden prop.***

*The "Bell Bowlers" (aka the "Buggers"); Jack Woolams in flight suit at center, summer 1943.*

Bob Stanley also proved that he knew a thing or two about improvisation. Disagreements between engineering and test operations had always been a part of the business. During the P-59 program, however, they were frequently amplified by the strong-willed and always impatient Stanley in what can only be described as forcefully decisive fashion. Early on, he and the other test pilots complained about the airplane's "snaking" (*i.e.*, directional instability) tendencies which were most pronounced at speeds above 290 mph. Bell design engineers were working on a modification that would reduce the size of the vertical tail and rudder but, in Stanley's view, they were dragging their feet. After a flight one day, he taxied in at high speed toward the open hangar, turned the aircraft and stopped abruptly, then gunned the engines briefly, blowing exhaust and dust on the men working inside. He got out of the cockpit and shouted to one of the crew chiefs: "Jack Russell, bring a hacksaw out here." Russell complied, whereupon Stanley proceeded to hack several inches off of the vertical tail and rudder. Then, after the surfaces were faired over, he climbed back in the cockpit, taxied out and took off. After landing, he muttered: "Works much better that way!" Jack Russell later recalled that they had to keep a fresh supply of hacksaw blades on hand because Bob Stanley continued to conduct his own unilateral modification program on the airplane.

Improvisation even carried over into security. Whenever the airplane was in a location where uncleared personnel might possibly catch a glimpse of it, Bell personnel threw a canvass tarp over it to cover the engine inlets and they mounted a dummy wooden prop on its nose. Remarkably, this simple ruse seemed to work even when unsuspecting observers came within

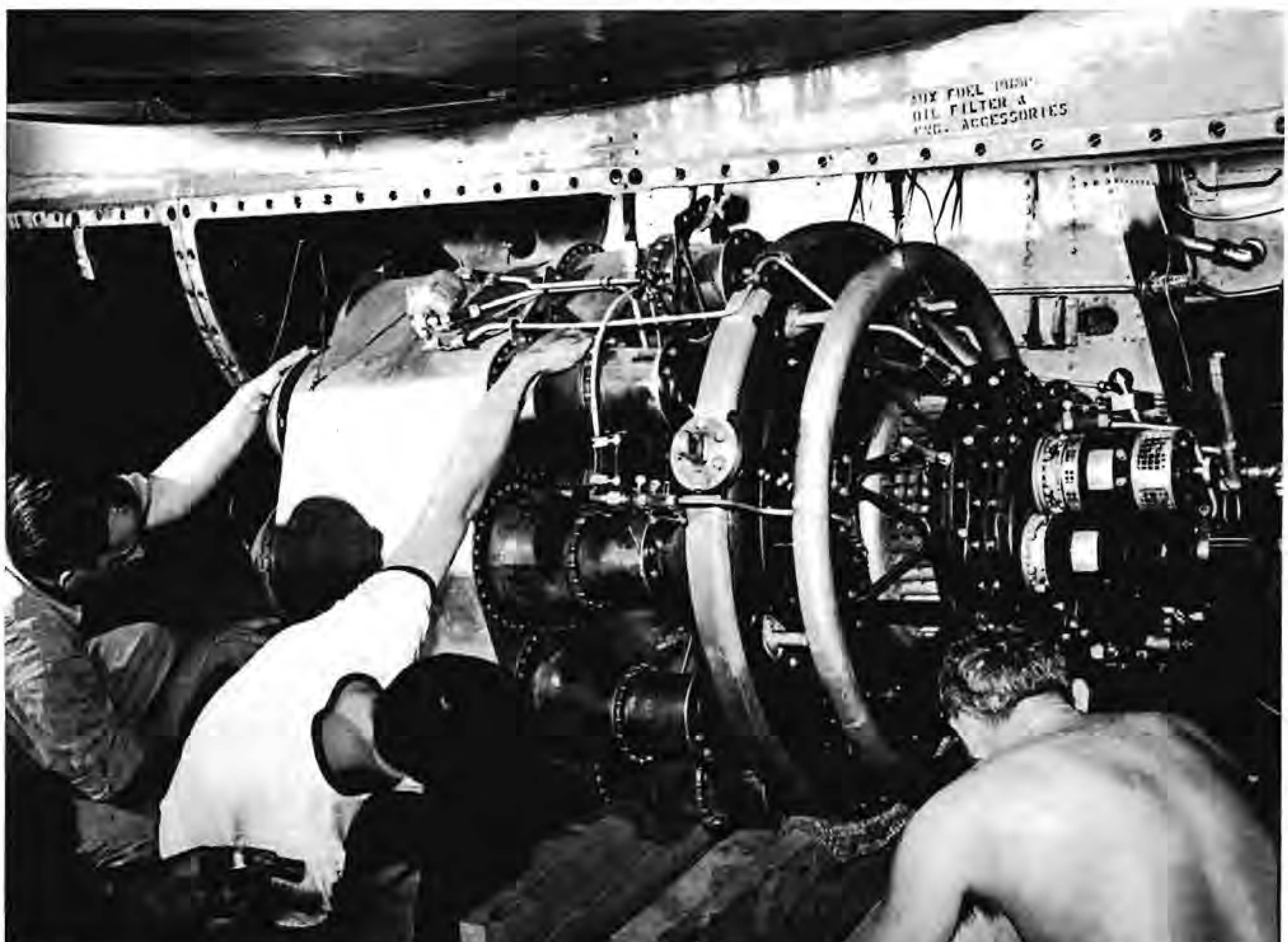
*Jack Woolams in the cockpit of an XP-59A wearing his derby hat.*

close proximity to the airplane because of their unquestioning assumption that props and airplanes just naturally went together.

This assumption ultimately enabled one of Bell's test pilots to have some fun when the program was downgraded from "Top Secret" status in the summer of 1943. Popular with all of his co-workers, Jack Woolams was a superb pilot and a prankster *par excellence*. After a weekend trip to Hollywood, he returned with a couple of dozen black derby hats and some fake moustaches. These he distributed amongst Bell personnel and, donning these symbols of jet service, the fraternal order of the "Bell Bowlers"—or, as they called themselves more informally, the "Buggers"—made appearances at roadhouses and other high desert establishments from Red Mountain to Mojave.

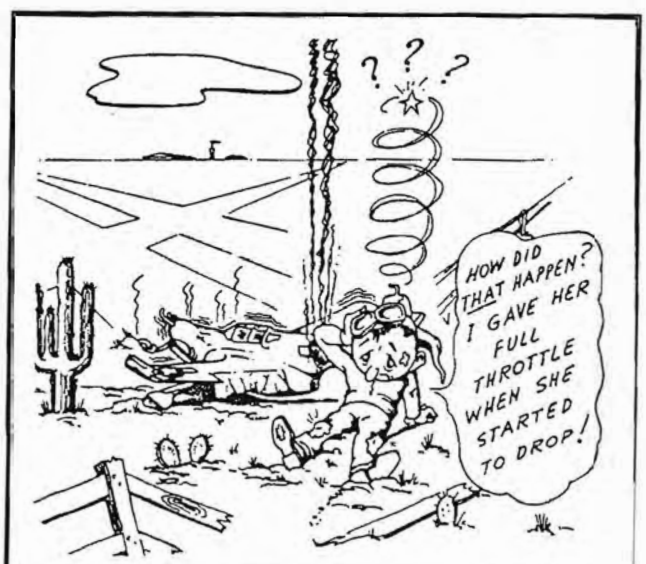
Jack Woolams, however, had additional plans for the derby hat. Even though the P-59 was no longer "Top Secret," very few had been informed of its existence—and this certainly did not include the fighter pilots who were in training across the lakebed at Muroc. Woolams, therefore, took it upon himself to provide a few of them with a rather disturbing introduction to jet-powered flight when he edged up alongside one of their P-38s. We can only imagine the pilot's shock when, first of all, he glanced over at this airplane without any *visible* means of propulsion! But he probably became even more disturbed when he peered up into the cockpit...and saw what appeared to be a gorilla, in a derby hat, jauntily waving an unlit cigar! The irrepressible Woolams then typically tipped his hat and pulled away or peeled off, leaving yet another bewildered airman to ponder his perceptions of reality. Tales of bent throttles began to filter back to the test base and, reportedly, psychologists and commanders over on the main training base succeeded in convincing these pilots that their eyes must have deceived them. After all, so the argument went, "*everyone* knows an airplane just can't fly without a propeller."

As the pilots became familiar with the characteristics of the prototype jets, they gained a lot of wisdom that they would ultimately incorporate into the flight manual. Rapid throttle transients to accelerate the aircraft, they found, caused engine surges that could burn up the turbines and combustors. The I-A engine's slow acceleration also taught them *never* to go low and slow on final approach. Lacking an airstart capability, the engines also had a nasty habit of flaming out and, as had been predicted, they consumed *enormous* quantities of fuel, limiting the airplane's endurance to an hour or less. Experience with both of these problems bore out the  was noteworthy at the time that the highly experimental P-59 program did not suffer a single seri-ous mishap and this was largely attributed to the availability of the lakebed. Moreover, in response to the fuel gulping tendencies of the engines, pilots



*The I-A engines originally had to be pulled for inspection and repair after just three hours of running time. The higher thrust I-16 engines that went into service by late 1944 sometimes totaled as many as ten hours of running time before requiring maintenance and repair.*

*Above and below right: Bell test pilots Jack Woolams (in cockpit) and Tex Johnston conferring before an XP-59A flight. Johnston later made the first flights of Boeing's YB-52 and Model 367-80.*




*Cautionary illustration from the official Pilot's Flight Operating Instructions warned pilots about the engines' poor acceleration and the hazards of going "low and slow" on final approach.*

routinely maximized mission time by flying until the tanks went dry and then gliding in to deadstick landings on the lakebed.

As the business of flight testing the airplanes and engines proceeded, the test team encountered more than its share of headaches. Early on, for example, they had so much trouble starting one of the engines that they named the No. 1 airplane "Miss Fire." Overheated bearings, malfunctioning fuel pumps and barometric controls, detached turbine blades, the 3-hour inspection requirement and countless other problems eventually forced them to remove the cowling panels so often that they later started calling it "Queenie," in honor of a much-admired exotic dancer (the designation "Airacomet" only came into use much later as a result of a contest among Bell employees). Indeed, persistent engine breakdowns and lengthy delays in the delivery of replacements, spare parts and uprated, higher-thrust models of the engine caused Bell's flight test program to fall way behind schedule.

As it was originally planned, the structure of the XP-59A test program was consistent with common practice throughout the early 1940s. Contractors normally performed the lion's share of flight testing on their own new aircraft. Typically, they spent a period of time troubleshooting unforeseen airframe or subsystem problems while demonstrating the airplane's airworthiness. This was supposed to be followed by a methodical envelope expansion program during which they collected performance data to be submitted to the Engineering Division at Wright Field. There were virtually no standardized practices throughout the aircraft industry. Each contractor typically employed his own test methodology, trained his own test personnel, used instrumentation designed and developed by his own test organization, and followed his own procedures for data reduction and analysis. Once the contractor had defined the aircraft's envelope and submitted his data to Wright Field, a test pilot and flight test engineer from the Flight Section's Flight Test Engineering Branch were typically assigned to go to the contractor's facility to conduct what were essentially contractor compliance verification tests. This usually encompassed a brief series of flights (typically extending for no more than 20-25 flying hours for fighter-type aircraft) during which they were to collect enough performance data to confirm or challenge the contractor's results. During these flights they would also evaluate the flying qualities of the airplane and perform initial assessments of its operational suitability. In preparation for these tests, the flight test engineers always calibrated Test Branch instrumentation before leaving Wright Field and then closely monitored its installation on the test aircraft at the contractor's facility. This whole process, from the contractor's first flight through the official military performance tests, normally required no more than 3-6 months to complete. The XP-59A effort, however, was not a "normal" program. No one in America had ever built and tested a jet airplane before.

***Larry Bell (center) and Col. Don Keirn (at right) on the ramp at the Muroc test base in the late spring of 1943. Bell lobbied hard for a production decision long before adequate testing had been completed.***

Program officials in the Engineering Division at Wright Field had expected to start receiving useful performance data by January 1943 but, by mid-April, the airplanes had only accumulated 29 flying hours. Despite the *extremely* limited amount of flying time—and the fact that only a miniscule amount of actual performance data had been collected, Larry Bell was ready to push for production. On April 27, Colonel M.S. "Mish" Roth, Chief of the Aircraft Projects Section, reported to Brigadier General Frank Carroll, Chief of the Engineering Division, that Larry Bell had recently visited the test base to witness flights of the airplane:

> ...it was his belief that he would take the latest performance and proceed to General Arnold's office with an immediate plan of action which conceivably could be a proposal to go to immediate production. This is Mr. Bell's normal

procedure in cases of this kind and it is, therefore, necessary that this office be prepared to submit a proposal of our own or at least have a clear picture of our proposed plans.

One thing was *very* clear at that point, the Engineering Division would require a lot more performance data and effective operational suitability evaluations before it would endorse any production decision. As Colonel Roth explained:

Colonel Swofford has pointed out that it is not known how good a military airplane this ship will be and that, in spite of Mr. Bell's enthusiasm, we should proceed with caution until its military usability has been determined. I believe that Colonel Swofford thinks there might be some objectionable features to the airplane which will not be satisfactory from the tactical standpoint: namely, the rather poor rate of climb and the lack of acceleration for low flying speeds.

"If Mr. Bell makes a proposal to go into production on this airplane," Roth counseled, "I believe it should be squelched."

Due, in part, to the late delivery of engines and engine parts, testing continued to progress at a snail's pace. Although the company continued to press for an immediate production contract, in late June, Bell management conceded that it had "underestimated the scope of the test work to be done on this new type of aircraft configuration." By August, the airplanes had only flown for a little over 90 hours and very little, if any, of this time had been dedicated to acquiring verifiable performance data. Indeed, the Bell-G.E. test team had been forced to spend virtually all of its time attempting to find and fix engine, airframe and systems problems and thus Bell's test pilots flew very few real performance test points.

The only military pilots who flew the airplanes throughout this period were project officers and high-ranking officials, not performance test pilots. As noted earlier, the project officers flew the aircraft periodically to troubleshoot problems and recommend or approve airframe or system fixes...and there were many such fixes to make. The XP-59As, for example, had been built with fabric covered flight control surfaces, a fact which prompted one Engineering Division official to mockingly ask when Bell was "going to quit making airplanes out of vegetable matter." Thus, after Colonel Swofford repeatedly encountered what he called a "flap vibration" problem on the XP-59A, he insisted that the flaps—and, indeed, all flight control surfaces—on the

***Crew chief Earl "Pop" Fisher assisting Jack Woolams before an XP-59A altitude flight. Note water on lakebed and smoke from what was an apparent aircraft accident.***

YPs and any potential production aircraft should be covered with metal skins.

Since the contractor testing fell so far behind schedule and since the XP-59A, with its highly experimental I-A engines, was not a production representative vehicle, the Engineering Division did not subject it to a formal evaluation conducted by an AAF test team. Instead, program officials decided to defer official performance tests to the YP-59A and they relied upon Bell to provide the final data on the XP-59's performance.

While there were certainly some noteworthy achievements, such as when Jack Woolams coaxed the No. 2 XP-59A to an unofficial American altitude record of 45,765 feet on July 14, 1943, the airplane's overall performance fell far short of expectations. In part, this was because the original thrust data provided by the British for the W.2B engine had been misinterpreted by the G.E. design team and thus the I-A's actual performance fell about 25 percent short of what had been very optimistic projections. Even with modified I-14 engines, each providing about 1,450 pounds of static thrust, the maximum reported speed attained by Bell was only 424 mph at 25,000 feet. This speed was attained, however, only after the entire airplane's surfaces had been puttied, smoothed and sanded and its wings polished. This "cleaning up" of the airplane was a practice for which Bell had been criticized in the past and the Engineering Division refused to accept the data as representative of the airplane's true performance. By comparison, in its combat representative "dirty" configuration, the XP-59A's top speed was only 404 mph at 25,000 feet.

Persistent engine and airframe development problems, delays in the delivery of a production-representative aircraft and engines, *and* the fact that the Bell and G.E. test teams found themselves in the position of having to figure *how* to test a jet airplane as they proceeded, all combined to delay the start of official AAF performance evaluations until late October 1943 when a YP-59A was finally ready for testing. Bell's hopes were riding on this airplane. The company's design engineers had projected top speeds in excess of 480 mph.

## *Official AAF Tests*

As was common practice in those days, the entire AAF test team for the official tests of the YP-59A consisted of just two men: test pilot Captain Wallace A. "Wally" Lien and flight test engineer Captain Nathan R. "Rosie" Rosengarten. Both were assigned to the Flight Test Engineering Branch of the Engineering Division's Flight Section at Wright Field. A superb airman with a degree in mechanical engineering from the University of Minnesota, Wally Lien was

*Captains Nathan R. Rosengarten (left) and Wallace A. Lien with XP-80 at Muroc, February 1944.*

one of only a handful of wartime AAF test pilots in the Flight Test Branch who were rated by their superiors as *bona fide* professional experimental engineering test pilots. Rosie Rosengarten had been mentored by veteran Wright Field flight test engineers Louis H. "Si" Sibilsky and Paul Bikle, who was then "writing the book" on performance flight testing and would go on to establish himself as one of the major pioneers in the field. Wally and Rosie made for an extraordinary team.

Even while making allowances for late deliveries of aircraft and engines, as well as the delays caused by engine and other airframe and system development problems, project personnel at Wright Field had been disappointed with the extremely limited and sometimes unreliable data provided by the Bell team after nearly a year of flight test operations. Many of them believed that the company had failed to employ a disciplined test process that would have generated "controlled flight test data" and that many of its claims for the airplane were largely based on somewhat optimistic extrapolations from precious few real data points. Bottom line, they required a sufficient volume of valid data on the airplane's performance, as well as reliable assessments of its flying qualities and combat potential, in order to make decisions regarding its future...and, indeed, the future of the whole turbojet program. That responsibility now fell on Captains Lien and Rosengarten.

Coming in at a gross weight of 10,600 pounds, some of YP-59s were representative of the ultimate production version of the aircraft. For example, the wingtips were clipped and squared off, reducing the span from 49 feet to 45 1/2 feet and its wing area by about 15 square feet. The size of the vertical stabilizer was reduced and its tip squared off, as well. The hinge-mounted, side-opening canopy, which was flush with the fuselage of the XP-models, was replaced by a new sliding canopy which protruded about two inches above the fuselage surfaces and a larger and flatter windscreen was also incorporated. Finally, the YPs were configured with the uprated I-16 models of the engine (AAF designation J31) rated at 1,650 pounds of static thrust (the thrust rating for which the airframe was originally designed). The first two YP-59s were delivered to the Materiel Center Test Base at Muroc in June of 1943. Since delivery of the I-16 engines had fallen behind schedule, however, the two aircraft were flown with I-A and I-14 engines throughout the rest of the summer.

When Wally Lien and Nate Rosengarten arrived at Muroc during the first week of September, the I-16 engines still had not arrived. Thus Lien immediately started flying one of the YP-59s configured with I-A engines in order to get a feel for the airplane's flying

*YP-59A (foreground) and XP-59A over Muroc.*

characteristics, the functionality of its cockpit systems, and to establish a documented baseline for comparison of the airplane's performance with the XP-59A and, later, with the production-representative airplane with full-rated power plants. This also gave Rosengarten an opportunity to check out his instrumentation and to begin to evolve a methodology for testing a jet airplane. During these tests, the YP-59 proved to be roughly 10-15 mph slower than the XP-59A at all altitudes and *far* short of expectations. Rosengarten reported back to the deputy chief of flight test at Wright Field: "The uncorrected data was turned over to Bell and, of course, when they worked up the data they cried about us being about 25-35 miles lower in speed than what they expected. This of course, is an old story with them and I didn't let it bother me because I knew they never ran tests on this particular airplane and, like all their test work, it is strictly theoretical calculations." While this was certainly not good news, Bell still had great hopes for significant improvement in the airplane's performance with the I-16s installed.

Shipment of I-16 units from the G.E. plant was delayed until mid-October. Lien finally commenced official AAF tests on October 20. From that point on, the lanky young test pilot methodically exploited every available minute of flying time in order to maximize the volume of data acquired on each flight. Rosengarten could only marvel at his consummate skill. "His collected data," he later recalled, "was perfect. Curves could be drawn through his calculated data so even reasonable fudging (averaging points of data) was unnecessary. It was always right on." As the tests progressed in surprisingly swift fashion, on-site project manager Randy Hall nervously reported back to Bell's chief engineer that Captains Lien and Rosengarten had "not released any information on performance with the I-16's."

Because engine surge problems initially limited the tests to altitudes below 20,000 feet, Lien and Rosengarten were forced to conduct their flying program in separate blocks separated by an extended interval. Nevertheless, flying with rare discipline and precision in what was effectively an experimental research program, Lien completed the official AAF performance evaluation of the YP-59 in just 20 hours of dedicated flying time and his flights yielded the first blocks of data considered reliable enough to provide a firm basis on which to make critical programmatic decisions. To everyone's surprise and disappointment, the top speed achieved by the aircraft was only 409 mph at 35,000 feet. This poor performance, in comparison with the lower-powered XP-model, was primarily attributed to its slightly greater weight and the substantial increase in drag caused by the new canopy and windscreen.

In their detailed report, Lien and Rosengarten also provided a lengthy list of other attributes that rendered the design unsuitable for operational combat service. Controllability at high altitudes (30,000 feet and above), for example, was rated "unsatisfactory" due to the "freezing tendency of the ailerons." Despite the airplane's low wing loading, its maneuverability was rated as "poor." The YP-59's "snaking" tendencies, they reported, "completely destroys the airplane's usefulness as a gun platform." The I-16 engines consumed enormous quantities of fuel, severely limiting the YP-59's combat radius. Although he managed to stay aloft for 1.75 hours for

*These images provide excellent views of the XP-59A's design features. Note the large engine inlets and sizeable wingspan.*

one mission, Lien's sorties averaged less than an hour and, like most other pilots, he maximized his flying time by remaining airborne until the airplane's tanks went dry. "The range [of jet aircraft]," he and Rosengarten reported, "must be considerably improved to compete with the present day fighter." "At best," they concluded, the P-59 "could be used as a transitional trainer to familiarize pilots with the operating characteristics of a jet type power plant."

Despite the disappointing performance of the airplane and engines, Lien and Rosengarten were very confident about the future of turbojet technology, in general. Although the engines still had to be pulled for inspection after just 10-12 hours of operation and completely disassembled after 20-25 hours, "the future possibilities of this type of power plant," they predicted, "are unlimited."

## *P-59 Postmortem*

The disappointing performance of the overall design was blamed on a number of factors. In September 1943, on-site project manager Randy Hall's plaintive cry to Bell chief project engineer Ed Rhodes belabored the obvious: "We need thrust - thrust - and more thrust." The low thrust-to-weight ratio and the oversized (scarcely laminar flow) wings were among the most obvious contributors. There were many other flaws, however, which could conceivably have been identified and remedied during the initial design process if the Bell team could have had access to reliable high-speed wind tunnel data. Their original calculations concerning boundary-layer effects and engine nacelle inlet area, for example, were way off the mark and, after the airplanes started flying, Bell was forced to experiment with various new configurations. The original 2.86 square foot inlet was ultimately reduced to 2.08 square feet but, even then, it was scarcely optimized for peak performance.

The failure to completely understand the dynamics of airflow within the nacelles led to a multitude of other problems. A lot of engineering effort was expended after the flight test program got underway, for example, attempting to reduce rear compressor inlet temperatures. As noted above, the aircraft also exhibited a directional "snaking" tendency that increased in severity with speed. Despite all of Bob Stanley's impromptu hacksaw efforts, Bell's repeated modifications to the vertical tail and rudder were to no avail and, as noted above, the aircraft was judged "unsatisfactory" as a gunnery platform during official AAF tests. The real source of the problem may actually have had little to do with the rudder. It may well have stemmed back, once again, to the failure to adequately understand nacelle inlet problems. During his evaluation of the YP-59, Wally Lien had observed the "snaking" tendency of the airplane and he had also reported what he called "buffeting" in the engine nacelles. At a symposium in late 1945, Benson Hamlin, one of Bell's key flight test engineers on the program, subsequently confirmed this when he reported that the snaking "is believed to be due to the very large inlet scoops in which it is possible for the inlet ducts on either side to alternately stall and unstall, causing a fluctuating air flow in the scoops or nacelles producing an unstable directional stability of the airplane."

Though it served as a useful testbed to explore the potential advantages—and pitfalls—of a radical new technology, the P-59 was really, for all practical purposes, a 350-mph airplane—no faster than the prop-driven fighters of its day. And, indeed, in formal operational suitability tests during which it was flown in mock combat engagements against P-38s and P-47s, it was outclassed in virtually every category by the conventional fighters.

If the airframe—which, of necessity, had been based on conventional design criteria—did not meet the AAF's future requirements, the same might be said for the engine. Based, once again, on urgent necessity, the engine was an adaptation of the Whittle centrifugal design. As early as mid-summer of 1943, program officials in the Engineering Division at Wright Field had already determined that, because of the need for dramatic increases in thrust and fuel efficiency, the long-term "trend will be toward the axial flow type of units."

Hoping to catch up in a hurry, the Army Air Forces had attempted to make the great leap from a proof-of-concept, experimental vehicle into a 500-mph combat fighter, all in one airplane. It was a bold hope, too bold.

Ambitious plans for a major production run were canceled. In addition to the three XP- and 13 YP-59A prototypes, only 50 production models came off of Bell's assembly line. Not suited for combat, they were used to train America's first cadre of jet pilots and maintenance personnel—a role which, indeed, made them unique among the first generation of jet aircraft. More important, still, was the fact that America's aviation industry went to school with this aircraft...and those in it learned their lessons well.

## *Lulu-Belle*

On January 8, 1944, just two days after the AAF first announced the existence of the P-59, another jet prototype was prepped for its maiden flight at Muroc. In contrast to the Airacomet, there was nothing conventional looking about this airplane. Designed by Kelly Johnson and delivered by his fledgling "Skunk Works" in just ***143*** days, the sleek, single-engined XP-80 *looked* like it was made for jet power...and, indeed, it was. Coming in at a gross weight of just over 8,800 pounds, it was powered by yet another British import, a British DeHavilland Halford H.1B centrifugal-flow turbojet rated at 3,000 pounds of static thrust. Skunk Works employees, who assembled on a hill overlooking the lakebed that morning, had affectionately nicknamed the airplane "Lulu-Belle."

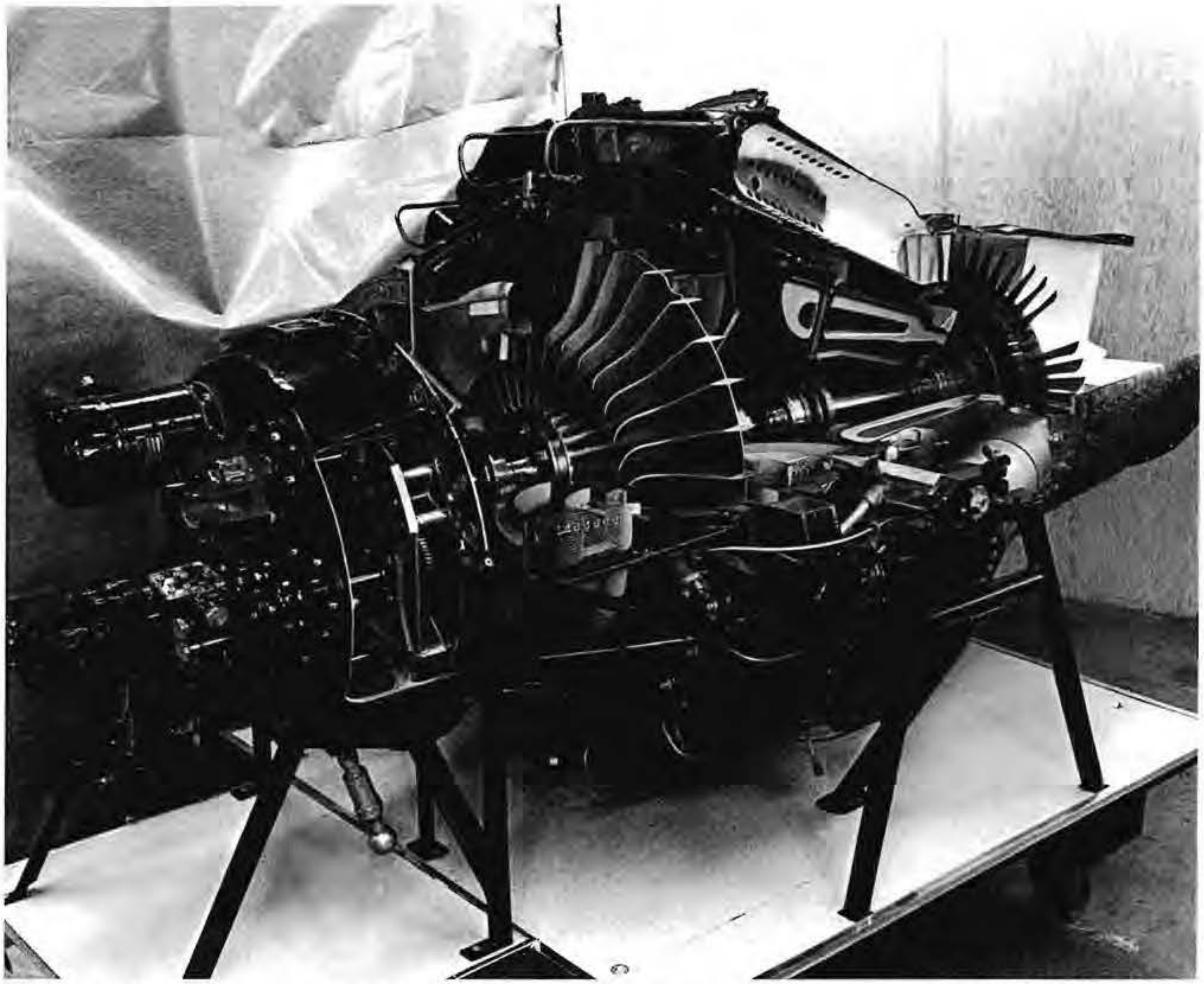
Shortly before Lockheed test pilot Milo Burcham entered the cockpit, Johnson told him: "Just fly her, Milo, and find out if she's a lady...or a witch." *She* proved to be a lady, indeed, as Burcham put on an impressive demonstration above the lakebed that morning. Afterwards, he reported that he had reached a maximum indicated airspeed (I.A.S.) of 490 mph "and everything felt solid." Toward the end of his demonstration, as one eyewitness reported, he "made a pass across the field at a terrific speed [475 mph I.A.S.], zoomed up to about 9,000 ft. rolling most of the way. A very spectacular show—everyone was very much impressed." Among those who were profoundly impressed was Bell test pilot Tex Johnston. Immediately afterward, he fired a cable back to Bob Stanley in Buffalo: "Witnessed Lockheed XP-80 initial flight-STOP-Very impressive-STOP-Back to drawing board-STOP."

Engineering Division officials on hand that day were also impressed and, this time, they were not about to wait a year to get an official AAF reading on the airplane's performance. After Burcham had completed just seven flights for a total of 2.47 flight hours, Captain Lien commenced his performance evaluation of the XP-80 on February 12. Teamed once again with Captain Rosengarten, over the next 27 days, he completed all required test points in just 12 flights for a total of 9.76 hours. Even though, throughout these tests, the Halford engine was limited by RPM

*Lockheed XP-80 on Rogers Dry Lake.*

*The XP-80 being prepped for its first flight at Muroc in the early morning hours of January 8, 1944. Note Skunk Works employees on hill overlooking the lake and Kelly Johnson, in stocking cap and overcoat, walking around the front of the airplane as he oversees the operation.*

*Test pilot Milo Burcham being congratulated by Kelly Johnson after first flight of the XP-80. To the left and just behind Burcham was Lt. Col. Marcus Cooper, project officer from the Experimental Aircraft Section at Wright Field. Cooper would later serve as AFFTC commander from 1957 to 1959.*



*G.E. I-40 (J33) centrifugal-flow engine. Uprated versions later provided more than 5,400 pounds of static thrust.*

restrictions to just 2,460 pounds of static thrust, the results were spectacular. During one of Lien's stabilized test points, the XP-80 became the first American aircraft to exceed 500 mph in level flight (502 mph at 20,480 feet). Needless to say, like everyone else, he was impressed with the airplane. "The zoom from high speed and the acceleration in a dive," he reported, "are astounding." He also observed that the maneuverability of the airplane was excellent and "an extremely high rate of roll was possible," somewhere "on the order of 360-degrees per second, at almost any speed from stalling to high speed." Spectacular as they were, the test results really only confirmed what officials at Wright Field had more or less anticipated.

By the time the XP-80 took to its wings, it had essentially become a proof-of-concept demonstrator for a much more ambitious design. Prior to the end of 1942, G.E. design engineers had already learned enough from their work with the original I-A engine for the Engineering Division at Wright Field to give the go-ahead to develop an engine that would more than triple the I-A's thrust. Development of the I-40 (J33) progressed so rapidly that, in August of 1943, the Engineering Division asked Johnson to design a substantially larger airframe to house a centrifugal-flow engine providing 4,000 pounds of static thrust. He readily accepted the challenge and, this time, he and his Skunk Works team delivered the XP-80A in an unprecedented ***132 days***! With Tony LeVier at the controls, this airplane first flew at Muroc in June of 1944. It was the prototype for America's first combat-worthy jet fighter, the P-80 "Shooting Star." The first production models were accepted by the Army Air Forces just eight months later, in February of 1945. Capable of speeds approaching ***600*** mph, the P-80 demonstrated how far and how fast the United States had come in just three years. The learning process launched by the XP-59 and I-A engine program was already yielding extraordinary dividends.

*Top photo: Kelly Johnson congratulating Tony LeVier after first flight of the XP-80A. Bottom left: Lockheed XP-80A (Rogers Dry Lake in background). Bottom right: On June 19, 1947, Col. Albert Boyd set a world speed record in a modified P-80R, averaging 623.7 mph during four low passes over the lakebed.*

## *Turbojets—The Foundation for Muroc's Destiny*

The turbojet engine defined Muroc's destiny. As noted above, the tests of the highly experimental X- and YP-59s were completed without serious incident at Muroc. Personnel from Wright Field, accustomed to contending with poor weather, an over-crowded flight line and the hazards posed by increasing congestion— both in the air and on the ground—could not fail to be impressed by the tremendous advantages afforded by the remote desert site. Captain Rosie Rosengarten was certainly among them. Following the completion of the YP-59A tests, he stayed on at Muroc to prepare for the upcoming XP-80 flights. Working late into the night in his small room in the Desert Rat Hotel on December 8, 1943, he drafted a memo that he hoped the chief of the Flight Section, Colonel Signa A. Gilkey, would forward up the chain to the commander of AAF Materiel Command. In it, he suggested that, if expanded and staffed with permanent personnel, the test base at Muroc could serve as an outstanding "alternative site" to the existing hub of flight test operations at Wright Field. He provided a long list of justifications for such an action. In addition to the fact that flight operations were possible during "98 percent of the year," the security of all projects could be much more easily insured at the remote location. An incomparable margin of safety was afforded by the existence of "approximately 100 square miles of take-off and landing space" on at least eight different dry lakebeds within a 50-mile radius. Tests requiring "extra smooth air" could be flown over the nearby Pacific Ocean. Flight test personnel stationed permanently at the facility would be readily available "for the flight testing of all experimental and production airplanes manufactured in the vicinity of the West Coast." Moreover, he estimated that "airplanes manufactured in the Eastern and Northern sections of the country could be flight tested in approximately one-third the time necessary at factory owned fields during the inclement months of the year."

While Rosengarten had proposed a build-up of the existing North Base site, when Gilkey and his deputy, Colonel Ernest K. Warburton, forwarded the memo up the chain for approval, they went a step further. They requested that the entire installation—including the major training base across the lakebed—be turned over to the Materiel Command to be used exclusively for flight test. When Brigadier General Frank Carroll, the chief of the Engineering Division, received the proposal, he solicited advice from his senior staff. They heartily endorsed the idea. Colonel Howard Z. Bogert, chief of the division's technical staff, for example, concluded that, "giving due consideration to the long-range picture and requirements of our postwar Air Force, we should strongly recommend the acquisition of the main base at Muroc as a completely going concern." He added:

> Muroc is the one place I know of within the continental United States where a pilot can take off with a new...airplane with highly experimental features embodied in its design, without the slightest worry as to what would happen if motor trouble occurred and other complications arose which would require immediate landing...The weather at Muroc is certainly infinitely better than it is at Wright Field, and many times better than at Eglin Field, as well.

Carroll endorsed the proposal and sent it up to the commander of the Materiel Command who, in February 1944, passed it up to Major General Echols who was now on General Arnold's staff in Washington. While Arnold was in the forefront of those who believed the AAF would have to mount and sustain a major postwar research and development effort, his immediate priorities were focused on winning the war. When Echols approached him about the proposal, Arnold told him to back off for the time being. The training mission was too crucial to the immediate war effort. He promised, however, "I'll give it to you as soon as the war is over." He proved to be as good as his word. Within days of the end of the war in the Pacific, the transfer of the installation had been approved and, on October 16, 1945, the entire base was transferred to the new Air Technical Service Command and flight test became the sole mission at Muroc.

While AAF flight test remained headquartered in the new Flight Test Division at Wright Field during the immediate post-war era, the die had been cast, as an ever-increasing volume of both AAF and contractor flight operations were staged out of the remote high desert base. All of America's first generation jets—both Air Force and Navy—would make their maiden flights there along with an impressive array of other unconventional airplanes.

When Walter C. Williams arrived at Muroc with a small contingent of NACA technicians to support the initial powered flights of the Bell X-1 in the fall of 1946, he was dazzled by the wide variety of new experimen-

***Brand new P-80As undergoing accelerated service tests on the ramp at the Muroc test base in late September 1945. By war's end, the base at the North end of the lake bed had grown into a sizeable complex. The original XP-59A hangar is at the far left of this image.***

tal prototypes he saw undergoing tests at the base—from AAF aircraft, such as the giant XB-35 Flying Wing and the jet-powered XB-43A and XP-84, to a surprisingly large array of Navy vehicles, including the jet-powered XFJ-1 and XF6U, as well as the turboprop XF2R-1 and the gargantuan prop-driven XR6O-1 *Constitution.* He had (correctly) heard rumors that the Air Force was developing a master plan for the construction of a major flight test facility at the base and his own experiences with the X-1 had already confirmed the wisdom of such a development. In this primeval setting, he had caught a glimpse of the future. Writing back to his superiors at Langley Field, in Virginia, he predicted the NACA would probably "have a large group out here for a very long time." "No two ways about it," he concluded, "this is the place to test experimental airplanes or, for that matter, any sort of airplane."

Walt Williams was prophetic. Already becoming synonymous with the turbojet revolution in America, Muroc—soon to be renamed Edwards Air Force Base—quickly became the center for the nation's experimental flight research, as well.


***The XP-84 (top), XB-43 light bomber (center), and the U.S. Navy's first jet, the XFJ-1 (bottom), all completed their first flights at Muroc in the year following the war. In September 1946, the second XP-84 set a U.S. national speed record of 611 mph at the base. Though the P-84 and FJ-1 went into production, all three of these experimental prototypes were, at best, transitional designs that were scarcely optimized for jet performance.***

*Brig. Gen. Laurence C. "Bill" Craigie, post-war Chief of the Engineering Division at Wright Field.*

*Capt. Wally Lien with General of the Air Force Hap Arnold after Lien had performed what reporters described as a "spectacular flight" in a P-80A at Mitchel Field, New York, in early August 1945.*

## *Some Lessons*

The turbojet airplane could have been—and, but for the delusions of Adolph Hitler, *might* actually have been—a decisive weapon in World War II. But it was not and, although the United States failed to put a jet aircraft into combat, with Germany's surrender and the development of the J33-powered P-80, this country had arguably moved from the back of the pack into the forefront of the turbojet revolution within a span of just three years.

How did we do it? Well, in large part, quite obviously because of tremendous advantages in terms of materiel, skilled manpower and industrial know-how. But also, in part and almost ironically, because of that very same focus on applied science that Edward Constant has argued initially put us behind. No nation in the world was more adept at—or had more impressive facilities for—transforming the fruits of pure science into superior products. In some cases, being first is not nearly so advantageous as being a really superior second, third, or even fourth. Once presented with a good idea, no nation was better prepared to run with it and a so-called weakness became an immediate strength.

Nevertheless, none of this would have been possible without the aid and ongoing assistance of the British and this lesson was certainly not lost on the man most intimately involved in the process. Returning from a trip to England in August 1943, Colonel Don Keirn was exasperated by the fact "that enough emphasis has not been placed on research facilities to enable this country to keep up with developments. Our present position," he concluded, "is largely due to the aid given us by Great Britain and our ability to sift the information and follow those lines which appear to be most immediately profitable." The implications of this insight extended far beyond the turbojet and they were not lost on *any* of those who had been involved in importing the new technology to the United States.

By the late summer of 1945, as the U.S. military was completing its inventory of Germany's massive R&D infrastructure, now-Brigadier General Craigie was preparing to take over as the chief of the Engineering Division. It would be his job to help build a new U.S. Air Force that could meet the challenges of the future. The recent war had taught that science and the warfare had become inextricably intertwined and in the future, he was convinced, there probably would not be time to borrow, let alone to catch up. In a speech to the International Aeronautical Society, he emphasized that the U.S. must "tear a page from the German book of experience and use it as a warning lest we forget that research can only rarely be hurried, that it must be continuous, and that most of it must be accomplished during years of peace." This, he further emphasized, would require the creation of a massive R&D establishment "prepared to stand on its own feet" within the Air Force and, he concluded, "these feet can only be provided through adequate appropriations and the provision of adequate personnel and facilities."

This was essentially the same message that Dr. Theodore von Karman and the AAF Scientific Advisory Group were about to deliver to General Arnold. And, indeed, he would define the establishment of a comprehensive and well coordinated R&D capability that would be second to none—one which would not only encompass the NACA, industry, and the universities but also, for the first time, a major in-house establishment, as well—as the AAF's highest postwar priority. The turbojet was the most publicized and, therefore, embarrassing example of the failure of the under funded, fragmented and uncoordinated pre-war military R&D system in this country. In that sense, it would become a useful symbol for those, like General Craigie, who were given the job of convincing an austerity-minded Congress—and, indeed, the rest of the Army Air Forces—that being first was no longer just a matter of national pride; it was now a matter of national survival.

## *Launching the Transformation*

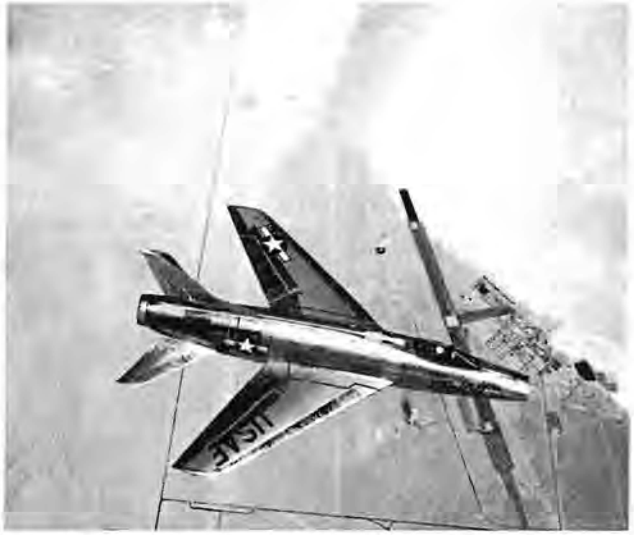
By war's end, the turbojet revolution was still in its infancy. The AAF already had at least 19 turbojet aircraft projects underway. Most of them, however, were relatively crude attempts to adapt existing airframe concepts to the new propulsion technology and even the most successful of them, such as the sweptwing F-86, could be considered as, at best, no more than transitional designs. G. Geoffrey Smith observed, at the time, that the turbojet revolution had precipitated a momentous turn of events: "...it is only as a result of successful development of the gas turbine and jet propulsion that engine manufacturers are able, for the first time in history, to supply more powerful units than the builders of airframes can at the moment usefully employ. The relative position [of each] has been reversed." On a very basic level, the genius of Whittle and von Ohain's vision of a high-speed airplane had been based on the perception that the engine and airframe were really two components of a single system joined together in a kind of symbiotic relationship in which the capability of each was dependent on the maximum efficiency of the other. Aerodynamicists had unwittingly brought on the demise of the reciprocating engine and now they found themselves in the position of having to catch up with the new technology which had been spawned by their efforts in order to take full advantage of its potential.

There was also, of course, a multitude of jet engine development projects underway at the time as the emphasis shifted overwhelmingly toward axial flow designs. General Electric, Westinghouse, and the erstwhile piston-engine manufacturers like Pratt & Whitney poured millions into a painstaking search for lighter weight, higher-strength and more heat-resistant materials as they strove to achieve higher compression and thrust-to-weight ratios and reduced fuel consumption while improving the durability and acceleration capabilities of their engines. Indeed, well before the end of the war, they had begun to make tremendous strides in the field of aerothermodynamics (achieving combustion in high-speed airflow). They had also started looking into the advantages to be gained from various types of thrust augmentation, such as water injection and afterburning, and they were already well aware of the tremendous fuel economies that could be achieved with turbofan designs.

The turbojet also compelled a host of developments in other fields. The tremendously high speeds and altitudes that were now within reach, for example, meant that human physiology could easily become the most critical limiting factor in the design of high-performance airplanes. Aeromedical research, a heretofore neglected field, suddenly became a top-priority endeavor, as did the development of ejection systems, pressurized cockpits, pressure-breathing oxygen systems, g-suits and full-pressure suits.

The turbojet also drove major efforts in weapon systems development. An immediate demand for dramatic improvements in lead-computing optical gun- and bombsights gave way to a massive effort to develop radar tracking systems and, among many, to the conclusion that guns and classic dog fights had become relics of a bygone age and only guided missiles could meet the requirements of future air-to-air combat.

High speeds and human limitations also compelled the development of hydraulically boosted and irreversible flight controls and stability and control augmentation systems. The development of sophisticated automated fire and flight control systems,



*The North American YF-100.*

*The Boeing KC-135A.*

*The Lockheed U-2A.*

in turn, mandated the development of compact, high-speed computers. The spin-off effects of the turbojet seemed to be endless.

Like an irresistible force, the awesome potential of the turbojet also forced designers to confront the reality of transonic flight. Aerodynamicists had long speculated on the possibility of flight beyond the speed of sound but it was now obvious that the means were at hand to actually propel a piloted airplane into that region. Speculation and theory were one thing but no one had any valid data on high-speed stability and control and the effects of compressibility and there was an urgent need for such information. Ezra Kotcher finally got his transonic research airplane, the Bell X-1, and the rest, as they say, is history.

## *Postscript*

The turbojet revolution reached maturity in this country within the brief span of a single decade. In fact, it can be argued the technology's coming of age was manifested in the development of a single engine design that powered five aircraft, each of which transformed the world of flight in a significant way. That engine was the Pratt & Whitney J57.

On April 15, 1952, almost exactly eleven years after Hap Arnold had first witnessed the E.28/39 making short hops during its high-speed taxi tests, eight prototype J57s—each providing about 8,700 pounds of thrust—powered the Boeing YB-52 on its maiden flight. By any standards, this engine-airframe combination was an extraordinary accomplishment. Early model B-52s could outpace an F-86E at altitude and they demonstrated an intercontinental range capability that, only a few short years earlier, had been thought to be impossible for jet-powered aircraft. For the first time in history, the "Buff" gave the United States a truly effective global power projection capability.

About a year later, in May of 1953, North American test pilot George "Wheaties" Welch lit the burner on his J57—boosting its thrust to about 13,000 pounds—and the YF-100 became the first aircraft in history to exceed Mach 1 on its maiden flight. From henceforth, supersonic flight became an essential component of air superiority (the U.S. Navy's first supersonic fighter, the Vought XF8U-1, was also powered by an afterburning J57 engine).

The versatile J57 also opened the door for a remarkable transformation of the whole travel industry. In July of 1954, four JT3s (the commercial version of the J57) powered Boeing's Model 367-80 on its maiden flight. The "Dash –80" was the prototype for the company's Model 707, the pathbreaking jetliner that quickly made air travel the standard mode of long-distance travel for the average person. It also served as the basis for the J57-powered KC-135 aerial tanker which, for the first time, provided the U.S. Air Force with a rapid global reach capability.

Just weeks after the Dash –80's debut, in August of 1954, Lockheed's Tony LeVier lifted off in a gliderlike aircraft from a remote desert lakebed. The airplane was powered by a specially modified J57 providing about 10,500 pounds of thrust. LeVier subsequently observed that the airplane climbed toward the heavens "like a homesick angel." The "angel" was Kelly Johnson's top secret U-2 and soon it would be cruising with impunity for hours in hostile skies at altitudes in excess of ***70,000*** feet.

With the arrival of aircraft such as these, the marriage of aerodynamics to thermodynamics was, at last, successfully consummated; for they were the first airplanes to achieve the kind of symbiotic harmony which, three decades before, had inspired the visions of Frank Whittle and Hans von Ohain.

***The Boeing YB-52***

## Appendix

# XP-59A Pilot Reports

## First Five Flights

R. M. Stanley. 10-2-67 (TWENTY FIVE YEARS LATER)

# PILOT'S REPORT

Place: Materiel Center Flight Test Base Flight #2

Pilot: Robert M. Stanley

Weather: Wind west, 20 m.p.h., C.A.V.U.

OK Ed Rhodes 10-2-67

Purpose: Shakedown Flight

Changes Since Last Flight: --

C.G. 26.1 %M.A.C. Gross Weight 9312 Pounds Time Take-Off 6PM

1. It was necessary to replace the ignition wire prior to satisfactory start of either engine. The ignition wiring is subjected to more heat than the insulation will stand and it appears inevitable that a redesign of this installation is necessary.

2. The airplane was completely standard as regards configuration for this flight. The aileron trim tabs were set for their maximum servo action. All trim tabs were neutral throughout the flight.

3. Flight testing began with fuel tanks approximately one-half full. The airplane was taxied approximately 3 miles down wind prior to take-off, during which time the interior of the cabin became somewhat stuffy from heat and engine fumes. Upon swinging into the wind for take-off, the engine fumes disappeared.

4. All take-offs were made using 15,000 r.p.m. on both engines with flaps fully up and with the airplane pulled off the ground at about 80 to 90 m.p.h. Throttle was applied promptly and acceleration during take-off appeared quite satisfactory. The run was estimated to be in the vicinity of 2,000 feet, possibly more. The first flight reached an altitude of approximately 25 feet, and landing was made using partial power without flaps. This take-off had the wind approximately 60° on the starboard bow and must be considered a cross-wind take-off.

5. Aileron and elevator action appear satisfactory, although the rudder force appears undesirably light causing the airplane to yaw somewhat for very light pedal pressures. Left rudder was needed for take-off due to cross wind.

6. While taxying back for take-off, the airplane ran at high speed over a small ditch approximately 4" deep without damage to the undercarriage.

7. During taxy and flight, all temperatures remained below their maxima.

Form C...

PILOT'S REPORT NO. 1 (CONT'D)

8. Two additional take-offs were made as previously described, the last reaching an elevation of approximately 100 feet. Landings were made using full flaps, the stalling speed apparently being between 70 and 80 m.p.h. for this loading. (Actual stall was not effected, although stick was fully back.)

9. The left hand generator and the radio transmitter did not function during these flights.

10. Fuel cross flow in all combinations was tried with satisfactory results. The electric boost pumps ran throughout the flights, although future doctrine will be attempted with these pumps inoperable to reduce fire hazard.

11. A final take-off was made with the wind approximately 45° on the port bow to check against previously reported left rudder requirement for take-off. On this flight right rudder instead was needed showing the rudder action to be apparently normal.

12. The landing characteristics of the airplane appear satisfactory although the lighting and surface condition adversely effect the pilot's depth perception causing all landings to be made slightly above stalling speed in a floating attitude.

13. The operation of the power plants cannot be considered satisfactory until they can be throttled to a lower thrust condition. At present the airplane floats a long way before landing can be effected due to the residual thrust coming from the power plant even when the throttle is fully closed.

14. The maximum speed obtained during these flights was 180 indicated m.p.h.

15. The retractable landing gear was not operated.

16. Approximately 52% of the design thrust of 1,640 lbs/engine was available from L.H. engine #170121 and from R.H. engine #170131 during this flight.

Total Flight Time To Date 30 Minutes

Form E4-1

# PILOT'S REPORT

Place: Materiel Center Flight Test Base Flight #2

Pilot: Robert M. Stanley

Weather: Calm, C.A.V.U., hot

Purpose: Shakedown Flight

Changes Since Last Flight: -- Light hatch installed, no observer or ballast

C.G. 26.4 wheels up 27.4 wheels down %M.A.C. Gross Weight 10,089 Pounds Time Take-Off 12:55PM

1. After considerable run as a result of the reduced thrust and heavy load, the airplane made a gentle take-off and after approximately 300 feet had been obtained the wheels were retracted. The latter did not go completely closed, The cockpit switch was returned to neutral to avoid damage to the landing gear motor.

2. After take-off the engine power rose to 15,500 r.p.m. and was throttled back to cruising figure of 15,000 which occurred with throttle approximately one-half open as judged by throttle quadrant position.

3. The landing gear horn blew throughout the flight while the wheels were retracted.

4. The airplane was climbed leisurely to 6,000 feet. Stalls were made with flaps up and flaps down. The stalling speed appeared to be about 80 indicated m.p.h., flaps down. The flaps up stall was not quite fully stalled.

5. A maximum speed of 160 indicated m.p.h. was attained.

6. The flight was terminated due to faulty action of the right engine's electric oil-pressure gauge. The trouble has been traced to a faulty electric transmitter and does not indicate faulty lubrication.

7. All temperatures were well within their maxima through the flight.

8. Fuel consumption appeared to be about 150 gallons per hour per engine.

9. The engines do not idle sufficiently slowly to facilitate landing in a small field. The landing itself is easily executed and not associated with any special technique.

Form C1-?

PILOT'S REPORT NO. 2 (CONT'D)

10. The heat in the cockpit is intense and is undoubtedly due to faulty ventilation control.

11. The change in trim due to change in power is entirely unnoticeable. The change in trim due to landing gear and flap operation is exceedingly mild. At the speed reported above, the airplane's handling qualities are excellent and all controls seem well coordinated. Steep turns were made in both directions and although the rate of roll is not high the forces are quite normal for the speed involved.

12. Approximately 52% of the design thrust of 1,640 lbs./engine was available from L.H. engine #170121 and from R.H. engine #170131 during this flight.

Total Flight Time To Date 50 Minutes

Form E4-1

| PILOT | DATE | BELL AIRCRAFT CORP. BUFFALO, N. Y. | MODEL | PAGE |
|---|---|---|---|---|
| CHECKED [illegible] [illegible] | DATE [illegible] [illegible] | | SHIP [illegible] 1 | REPORT 1-16 27-923-001 |

## CALIBRATED FLIGHT DATA

Flight No.:

Gross Wt. 2 Lbs. C.G. @ % M.A.C.

| INST.NO. | INSTRUMENT 10000 | 1 | 2 | 3 | 4 | 25.4 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | Altitude | | 1000 | 6000 | 10000 | | Maximum Allowable Temperatures | | | |
| | Recorded Airspeed | | 150 | 140 | 140 | | | | | |
| | R.H. Engine R.P.M. | | 15000 | 15000 | 15000 | | | | | |
| | Tail Pipe Temp. R.H. | | 1050 | 1050 | 1030 | | 1200 | | | |
| | Fuel Pressure R.H. | | 230 | 220 | 190 | | | | | |
| | R.H. Oil Pressure | | 5 | 6.5 | 6.5 | | | | | |
| | R.H. Turbine Inlet T. | | 1586 | 1663 | 1663 | | 1600 | | | |
| | | | | | | | | | | |
| | Left Hand Engine | | | | | | | | | |
| | R.P.M. | | 15000 | 15000 | 15000 | | | | | |
| | Tail Pipe Temp. | | 1050 | 1050 | 1050 | | 1200 | | | |
| | Fuel Pressure | | 230 | 210 | 180 | | | | | |
| | Oil Pressure | | 6.5 | 6.5 | 6.5 | | | | | |
| | Turbine Inlet Temp. | | 1586 | 1596 | 1586 | | 1600 | | | |
| | | | | | | | | | | |
| | L.H. Generator T. | | 104 | 104 | 86 | | 194 | | | |
| | L.H. Bearing T. | | 176 | 194 | 194 | | 392 | | | |
| | Temp. on Fuse. Muffle | | | 302 | 284 | | 482 | | | |
| | R.H. Bearing Temp. | | 266 | 266 | 266 | | 392 | | | |
| | Temp. on R.H. Boom | | 212 | 230 | 293 | | 392 | | | |
| | Temp. at rear of | | | | | | | | | |
| | R.H. Nacelle | | 257 | 248 | 248 | | 392 | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

Remarks:

Form 151

All temperatures are in degrees Fahrenheit

| | | | |
|---|---|---|---|
| BY Stanley | DATE 10/2/42 | BELL AIRCRAFT CORP. | MODEL XP-59A | PAGE 1-17 |
| CHECKED R M Stanley | DATE 10-14-42 | BUFFALO, N. Y. | SHIP 1 | REPORT 27-923-001 |

## PILOT'S REPORT

Place: Materiel Center Flight Test Base Flight # 3

Pilot: Robert M. Stanley

Weather: Calm, C.A.V.U.

Purpose: Shakedown Flight

Changes Since Last Flight: Hatch removed, installed nose cockpit cowl, cut fuel tank vents, installed L.H. tail pipe gaskets, power plant inspected.

C.G. ~~27.4 wheels up~~ 26.4 wheels down %M.A.C. Gross Weight 10,056 Pounds Time Take-Off 3:25PM

1. Following take-off, the airplane was climbed immediately to 10,000 feet at which elevation the cockpit is uncomfortably cold as the result of having no hatch. No undue aerodynamic disturbances such as buffeting accompanied the removal of the cabin hatch.

2. The power plant operated entirely satisfactory as previously reported.

3. The airplane's rate of climb seemed to be close to 1,000 feet per minute although it was not accurately measured.

4. The engines increase in r.p.m. with altitude requiring throttling back to maintain desired r.p.m.

5. The landing gear retracted completely this flight.

6. Using 15,000 r.p.m., the speed in level flight at 10,000 feet was surprisingly high and the airplane was throttled to avoid exceeding 250 indicated m.p.h. (This fact should not be considered as accurate pilot data, however, due to the qualitative nature of the flight.)

7. Fuel was observed to syphon from the right wing throughout this flight. The left wing, whose wing tank vent had been altered prior to this flight, did not appear to exhibit this adverse tendency.

8. A pull-up to 2g acceleration was made as well as steep turns of approximately the same acceleration.

9. Approximately 52% of the design thrust of 1,640 lbs/engine was available from L.H. engine #170121 and from R.H. engine #170131 during this flight.

Total Flight Time To Date 1 Hr. 15 Min.

Form C1-7

| | | | |
|---|---|---|---|
| BY Stanley DATE 10/2/42 | BELL AIRCRAFT CORP. | MODEL XP-59A | PAGE 1-18 |
| CHECKED R M Stanley DATE 10-19-42 | BUFFALO, N. Y. | SHIP 1 | REPORT 27-923-001 |

## PILOT'S REPORT

Place: Material Center Flight Test Base Flight # 4

Pilot: Colonel L. C. Craigie

Weather: Calm, C.A.V.U., hot

Purpose: Familiarization

Changes Since Last Flight: Cut right vent line, installed hatch

C.G. 26.4 wheels down, 27.4 wheels up %M.A.C. Gross Weight 10,089 Pounds Time Take-Off 5:20 PM

1. The airplane was flown by Colonel Craigie for purposes of familiarization. The cockpit hatch was installed this flight.

Total Flight Time To Date 1 Hr. 55 Min.

Form C-7

| | | | |
|---|---|---|---|
| BY Stanley DATE 10/2/42 | BELL AIRCRAFT CORP. | MODEL XP-59A | PAGE 1-19 |
| CHECKED RM Stanley DATE 10-18-42 | BUFFALO, N. Y. | SHIP 1 | REPORT 27-923-001 |

## PILOT'S REPORT

Place: Materiel Center Flight Test Base  Flight # 5

Pilot: Robert M. Stanley

Weather: Calm, C.A.V.U., hot

Purpose: Shakedown Flight

Changes Since Last Flight: None

C.G. 26.4 wheels down / 27.4 wheels up %M.A.C.  Gross Weight 9,300 Pounds  Time Take-Off 5:05PM

1. After take-off the wheels failed to retract completely and stalled about one-half way up. The cockpit switch was returned to neutral, then again flipped to the up position following which was heard a metallic sound as of someone stepping on a tin can or a piece of glass. The landing gear was then extended and the cycle repeated with the same results. In trying it by hand, it was found that the landing gear would come up easily by hand but the effort involved discouraged attempting to bring the gear entirely up by this method in view of the short amount of daylight still remaining so a landing was made.

Total Flight Time To Date 1 Hr. 40 Min.

Form C1-7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