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34. Donald Macintyre, *The Battle for the Mediterranean* (New York: W. W. Norton, 1964).

35. John B. Lundstrom, *The First Team: Pacific Naval Air Combat from Pearl Harbor to Midway* (Annapolis, Md.: Naval Institute Press, 1984), pp. 307–419.

36. Richard B. Frank, *Guadalcanal: The Definitive Account of the Landmark Battle* (New York: Random House, 1990), p. 207.

37. Von Kroge, *GEMA*, pp. 55, 69, 92–93.

38. Trenkle, *Funkmess*, pp. 93–98; Reuter, *Funkmess*, pp. 91, 98.

CHAPTER 9

Innovation and the Development of Flight ed. Roger D. Launius (College Station: Texas A+M U.P., 1999), 207-234

Rocket Aircraft and the "Turbojet Revolution"

The Luftwaffe's Quest for High-Speed Flight, 1935–39

MICHAEL J. NEUFELD

On 15 June 1939, Erich Warsitz made a brief and shaky flight around the Peenemünde-West airfield in the Heinkel He 176, the world's first pure rocket aircraft.[1] Ten weeks later, on 27 August, Warsitz took off from the Heinkel works at Rostock-Marienehe in the world's first turbojet airplane, the He 178. These two highly secret flights symbolized the dramatic advances that the Third Reich and its aviation industry had achieved in only a half-dozen years, and they made Germany the leader in advanced aeropropulsion. The second flight was also a milestone in what Edward Constant has called the "turbojet revolution"—a fundamental transformation of aircraft propulsion, design, and performance that began in the 1930s.[2]

That these two aviation "firsts" were achieved in Nazi Germany is well known. Yet for fifty years their military-organizational context has been misunderstood. To a great extent, the ghost-written memoirs of Ernst Heinkel, whose company built the He 176 and 178, have determined that context. Heinkel depicted both aircraft as his private initiatives, carried through against official indifference and even hostility on the part of the Luftwaffe (air force) and its bureaucratic arm, the *Reichsluftfahrtministerium* (Reich Air Ministry, or RLM). Heinkel was willing to share the credit only with Erich Warsitz and with the brilliant engineering physicists who pioneered rocket and turbojet propulsion in Germany: Dr. Wernher von Braun and Dr. Hans von Ohain, respectively.[3]

Heinkel's memoirs were shaped, not surprisingly, by the egotism of an energetic industrialist, and they contain errors typical of a book based on later interviews. But Heinkel's specific views of the Air Ministry were molded first and foremost by anger and injured pride. Despite his historic role in ushering in a

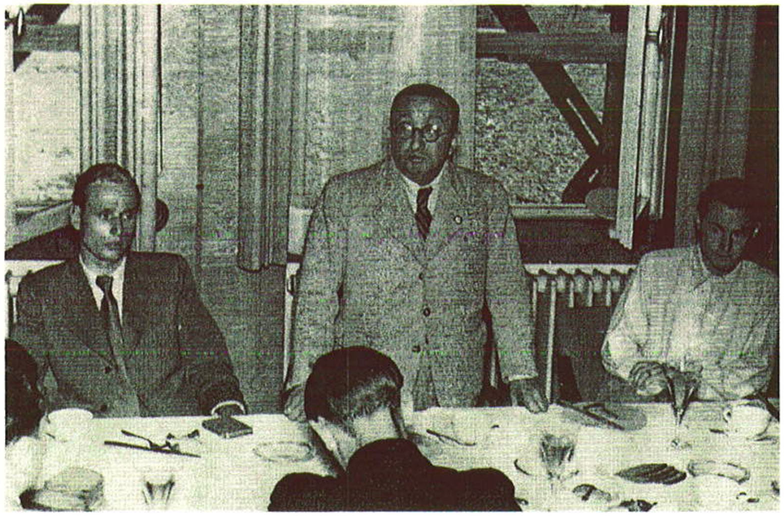

Fig. 9.1. Ernst Heinkel (center) speaks, probably at a celebration of the first turbojet flight in history in August 1939. At left is the test pilot Erich Warsitz, and at right the physicist-inventor Dr. Hans von Ohain. Courtesy National Air and Space Museum, 80-1894

new era of flight, the RLM gave a rival, the designer Willi Messerschmitt, the contracts for the Me 163 rocket interceptor and Me 262 jet fighter that entered combat in mid-1944. According to his biographer, Heinkel never got over his disappointment.[4]

Heinkel's account of the origins of German rocket and jet aircraft has been often repeated. Popular histories have mostly followed him without question, depicting the Luftwaffe as bumbling and slow in taking up the new technologies.[5] The more recent scholarly works of Edward Constant and Ralf Schabel have corrected Heinkel insofar as they have discussed the Air Ministry's active intervention in turbojet development after the spring of 1938—in the wake of its discovery that Heinkel had been funding von Ohain's revolutionary engine work since April 1936. But these valuable monographs only repeat Heinkel's claim that he had first begun supporting reaction-propulsion research in November 1935, after making an essentially private arrangement with von Braun, the key engineer in Army Ordnance's liquid-fuel rocket project.[6]

The organizational improbability of this arrangement should have raised questions, but no easily available sources clearly contradicted Heinkel's story.[7] Long overlooked, however, were Army Ordnance rocket files now in Freiburg

and Munich, many of which are accessible on microfilm.[8] Although dominated by army concerns, these records reveal that the Air Ministry, not Heinkel, originated research into aircraft reaction propulsion in 1935. The air force began an energetic rocket program in collaboration with Ordnance, financed ramjet and pulsejet engine research as well, and then added an independent rocket development capability. When RLM officials discovered the turbojet work at Heinkel, I will argue, their longstanding interest in reaction propulsion facilitated a quick decision to promote the new technology. In Britain, by contrast, the inventor Frank Whittle had already envisioned the gas turbine as a jet engine in 1929–30, but he struggled for years against official indifference. To understand the context of the "turbojet revolution" in Nazi Germany, it is therefore important to examine the origins of the Luftwaffe's quest for high-speed flight.

THE RISE OF AN INTERSERVICE ROCKET-AIRCRAFT PROGRAM

Before 1935, the Air Ministry Technical Office and its chief precursor, Section 8 (aviation) of Army Ordnance Testing Division, had shown little interest in the rocket. According to an October 1934 document, the RLM had made "agreements" with Ordnance, leaving the army in exclusive control of it. These agreements reflected not only Air Ministry indifference but also Ordnance's campaign to eliminate amateur rocket groups and monopolize the technology. Army artillery specialists, led by Testing Division Chief Gen. Karl Becker, felt that absolute secrecy was necessary to conceal from the world Germany's interest in a potentially revolutionary new weapon: the long-range ballistic missile. In late 1932 Becker set up a small liquid-fuel rocket project at the Kummersdorf artillery range outside Berlin, as liquid fuels promised much higher performance than existing solid propellants.[9]

Because the Air Ministry had only existed since the Nazi seizure of power in 1933, when Hitler had created it for Hermann Göring, RLM officials had to focus on their main task: forging a clandestine air force as a minimal deterrent against attack during the early phases of rearmament. (The Versailles Treaty had forbidden Germany any military aviation, although the army had carried out some covert training and purchase of aircraft.) Under the circumstances, exotic new propulsion systems that might allow flight at speeds of over 800 km/h (500 mph), the practical upper limit for propeller-driven, piston-engine aircraft, must have seemed distant, utopian, even absurd. Germany scarcely possessed adequate combat aircraft that could fly at half that speed.[10]

Yet there were reasons why the new service would quickly become receptive to radical new technologies like the rocket. Lacking an entrenched establishment, the Luftwaffe was more open to revolutionary technological ideas than western air forces. It was also imbued, as were the army and navy, with a desire to quickly make Germany competitive with, or superior to, other powers; technological zeal combined easily with a nationalist or National Socialist zeal for rearmament. Moreover, the improving economy, Hitler's aggressive rearmament policy, and the weak Western response to his violations of Versailles, meant ever-expanding resources for the Luftwaffe, especially after its official unveiling in March 1935. Finally, German theoreticians closely connected to the Air Ministry were the international leaders in high-speed aerodynamics. They, as much as anyone, recognized that the propeller-driven aircraft would in a decade or less reach the limits of its performance.[11]

But the proximate cause for the Luftwaffe's sudden interest in the rocket appears to have been a single individual: Maj. Wolfram Freiherr von Richthofen. A cousin and squadronmate of the Red Baron of World War I fame, he was an ace himself, having shot down eight enemy airplanes in 1917–18. Later a Field Marshal and one of the Luftwaffe's most successful operational commanders, von Richthofen had acquired an engineering doctorate in the 1920s and become head of the Technical Office's Development Division in 1933. According to von Braun, von Richthofen came to Kummersdorf in January 1935 and showed a lively interest in Army Ordnance's liquid-fuel rocket work. Not coincidentally perhaps, in mid-January Ordnance had presented films and lectures about the successful launches of two A-2 rockets to a group that included at least one unnamed RLM official.[12]

On 5 February, von Richthofen discussed rocket development in a meeting at his office. The next day, he wrote to Testing Division's ballistics and munitions section, which ran the army rocket project, about an accident in Dessau. An explosion there had injured an official of Germany's largest aircraft firm, Junkers, revealing its financing of liquid-fuel rocket development by Johannes Winkler, a pioneer of the spaceflight movement of the late Weimar Republic. A week later von Braun and one of his superiors, Capt. Leo Zanssen, went to Dessau to investigate and to impress upon Junkers Ordnance's obsession with secrecy. The results of the investigation, plus a company report probably written by Winkler, were passed along to the Air Ministry, which awaited them with interest.[13]

The relationship between the two services deepened in March, when Zanssen and von Braun, Dr. Lorenz of the Technical Office's Research Division, the aerodynamicist Dr. Adolf Busemann, the designer Willi Messerschmitt, and others observed Paul Schmidt's pulsejet experiments in Munich. Schmidt was

an independent inventor who had been working since 1930 on the pulsejet, a form of air-breathing reaction propulsion with intermittent combustion. In heavily modified form, his invention would propel the Luftwaffe's V-1 cruise missile or "buzz bomb" launched by the thousands against Britain and Belgium in 1944–45. But in 1935 the Luftwaffe was mainly interested in the pulsejet's possibilities for aircraft propulsion. Zanssen and von Braun attended because it was thought that the army might wish to pursue an automatic "aerial torpedo"—what we would now call a cruise missile—a concept seen as closer to an artillery projectile than an unmanned airplane. The upshot was that Ordnance contributed half of the research funds in a joint agreement with the Air Ministry, which would supervise the work. But both sides saw that Schmidt was years away from a practical propulsion system.[14]

It was not the first time the cruise missile idea had been broached. In October 1934 the engineer-inventor Hellmuth Walter had contacted Gen. Becker about the possibility of an "aerial torpedo" based on a ramjet. (A ramjet is essentially a tube that compresses air solely by the ram effect of the inlet at high speeds. The air is then burned with a fuel—Walter suggested oil—to produce thrust.) Since a ramjet, like a pulsejet, has to be boosted to a high velocity to work, Walter had proposed burning the fuel in a rocket engine with highly concentrated hydrogen peroxide until supersonic cruise velocity was reached. He had already been working with the navy since 1933 on hydrogen peroxide as a propellant for U-boat turbines and torpedoes.[15]

Before contacting Becker, Walter also had discussions with the Air Ministry on using the rocket/ramjet combination in "high-speed aircraft," and later claimed to have proposed some sort of turbojet engine as well. But his ideas had no apparent impact on the RLM. No one had yet demonstrated that a gas turbine would be adequately efficient for aircraft propulsion, and the ramjet concept, which had been known since at least 1913, was still beyond the existing technology. With Luftwaffe support, Walter did carry out exploratory experiments several years later. Meanwhile, Ordnance began to act as a consultant to his hydrogen-peroxide rocket development in late 1934, without investing any money.[16]

While the ideas of Walter and Schmidt must have seemed technically immature, the Technical Office's growing contacts with Kummersdorf had converted von Richthofen into a believer in the rocket—the one reaction-propulsion technology that appeared within reach. On 10 May 1935, he met Zanssen to discuss the possibility of a Luftwaffe-Army-Junkers experimental rocket-plane program. Zanssen explicitly mentioned the aviation section's earlier lack of interest. Von Richthofen was of quite another opinion. In the future, he argued, bombers could attack at high speeds and at altitudes of over 10,000 meters (33,000 feet). They would be above the ceiling of antiaircraft fire, and it would be difficult for slow-climbing, propeller-driven fighters to intercept them. A rapid-reaction, high-speed interceptor would therefore become essential. It was basically the concept that would later appear as the Me 163 "Komet."[17]

On 22 May, Ordnance replied, endorsing the feasibility of a joint rocket-aircraft program but expressing reluctance about revealing anything to Junkers. Ordnance ruled out working with the Winkler group altogether because the primary application of the rocket was the "liquid-fuel long-range missile," and its secrecy had to be protected at all costs.[18]

A little over a month later, on 27 June 1935, the Technical Office, Ballistics and Munitions, and Junkers met at Kummersdorf to view a rocket firing and discuss terms. Prof. Otto Mader, the head of development at the Junkers Engine Company, attended, as did von Richthofen and von Braun. For this meeting the twenty-three-year-old von Braun wrote a seminal position paper. Because a missile rocket engine was little different than one for an aircraft, he stated, it is "therefore advantageous that in the future as well, the development of the free-flying liquid-fuel rocket and the aircraft rocket engine could be carried out by the same center. Wa.Prw.1 [Ballistics and Munitions] believes that this goal can be achieved through the future creation of an 'experimental rocket establishment.'" This center should have some air force personnel, but they would be transferred to the employment of the army or the center.[19]

At the 27 June meeting, von Richthofen let it be known that the Luftwaffe was not going to be a junior partner in any joint "experimental rocket establishment." He also objected to the restrictive conditions that von Braun and Zanssen had laid down for cooperation with an aircraft firm like Junkers. But he made these remarks in a friendly way only after explaining his rocket interceptor concept: the goal should be an aircraft that could, after a forty-five-second boost, coast up to 15,000 m (50,000 ft) and then glide or cruise at high altitude for some minutes. As a preliminary step, a small experimental rocket plane could be tested, perhaps by towing it into the air and igniting the engine. Junkers would begin the preliminary design; von Richthofen had earlier cleared this arrangement with Mader.[20]

During the summer, the RLM brought Ernst Heinkel Aircraft into the program as well. Heinkel's fascination with high-speed flight was well known; it is also possible that the airframe side of Junkers—technically a separate company until 1936—may not have supported Mader. At the beginning of September, Army Ordnance, the Air Ministry, Heinkel, and Junkers signed a joint agreement protecting the secrecy of Ordnance's rocket development. Only five or six people at each firm were to be informed, and rocket-aircraft development was to be carried out in closed workshops. In late October or November, the Kummersdorf group received a Junkers "Junior" single-engine light plane to experiment by installing a 300 kg thrust liquid-oxygen/alcohol engine in the tail—the motor that had been used to power the A-2s. The funding and arrangements for these tests were made through Dr. Adolf Baeumker's Research Division of the Technical Office in collaboration with the quasi-governmental German Research Establishment for Aviation (*Deutsche Versuchsanstalt für Luftfahrt*, or DVL) in Berlin-Adlershof. These experiments aimed at developing takeoff-assist rockets for overloaded bombers as well as gaining experience in rocket-plane work. Junkers itself dropped out in fall 1935. The reasons are unknown, but Prof. Mader, who was a conservative piston-engine specialist, may have been unenthusiastic, or perhaps he did not see the point of Junkers Engine participating if Winkler's in-house group was excluded and propulsion development was run by Kummersdorf.[21]

Thus Heinkel's firm became the sole airframe contractor. On 16 October, von Braun and his chief designer, along with two RLM engineers, met Heinkel and his top designers at the Marienehe plant. They discussed the character of Ordnance's rocket technology and how it might be adapted to an airplane. The ultimate decision was to pursue an interim project before the construction of a pure rocket aircraft. A rocket engine would be installed in the tail of an He 112, the loser to the soon-to-be-famous Messerschmitt Bf 109 in the single-engine fighter competition of 1935. In December the firm specified an engine thrust of 1,000 kg (2,200 lb). That same month von Braun requested 200,000 marks (about $50,000) from the RLM for "Project 112 R," noting that speed was crucial since the work had already begun.[22]

MASSIVE INVESTMENTS—AND MOVES TOWARD INDEPENDENCE

By the end of 1935, both the Junkers Junior and the He 112 projects had been launched. But the most important product of the army-Luftwaffe alliance was yet to come. Shortly after New Year's, Wernher von Braun's concept of a secret "experimental rocket establishment" would bear fruit. Following his discovery after Christmas of a suitable site for an airfield and missile test range—near the fishing village of Peenemünde on the Baltic island of Usedom—the two services agreed to jointly fund it. The projected construction cost was 11 million marks for the first year alone—roughly ten times the Third Reich's expenditure on liquid-fuel rocket research for 1935. By April 1936, both services' leaderships had approved the deal, the land was purchased, and construction began. Only a year later, in spring 1937, von Braun and members of his Kummersdorf group would begin moving into the army section, Peenemünde-East. The Luftwaffe group began forming at Peenemünde-West later in 1937, and Uvo Pauls, who had been responsible for rocket engines in the Technical Office since mid-1936, became head in early 1938.[23]

The Air Ministry's commitment to Peenemünde—which began with a promise of 5 million marks from Research Division Chief Baeumker at a time when he had a virtual carte blanche from Göring to expand his facilities—was not the RLM's only new investment in rocketry in 1936.[24] Baeumker's division also lured an Austrian, Dr. Eugen Sänger, to set up an institute at a huge aeronautical research complex to be built near Braunschweig, and both the Research and Development Divisions began to fund Hellmuth Walter's hydrogen peroxide work in Kiel. While the destruction of the Luftwaffe archive in 1945 makes it difficult to discern the policy decisions that lay behind these initiatives, let alone the role of high-ranking leaders like Göring, the air force was clearly ensuring that it had a liquid-fuel-rocket capability independent of the army.

Sänger's hiring came first. A rocket experimenter and professional engineer, he submitted a rocket-aircraft proposal to the Germans in 1934 after its rejection by the Austrian military. Ordnance was not highly interested but eventually suggested that the Air Ministry might want to look into his theoretical investigations of rocket aircraft—indeed, Sänger's 1933 book had discussed his lifelong obsession, an orbital space plane, and a December 1934 article outlined a rocket-fighter concept that might have influenced von Richthofen. But in October 1935, after the founding of the alliance, von Braun recommended against the ministry hiring him on the grounds that his efforts would be duplicative.[25]

Research Division ignored this advice and offered Sänger a contract. Assigned to the DVL in Berlin, starting in February 1936, Sänger's first task was to search for a location for a rocket institute and test center to be affiliated with Braunschweig. Construction of this institute, near Trauen, began in 1937 under a cover name, with the apparent intent of obscuring its existence as much from the army as from foreign intelligence services! The Trauen facilities, built at a reported cost of 8 million marks, included a massive liquid-oxygen plant and a test stand for rocket motors of up to a 100 metric tons (220,000 lb) of thrust—both duplicating facilities at Peenemünde-East. Sänger's group began work there in 1938, tested a 1,000 kg thrust liquid-oxygen/diesel-oil rocket motor in 1939, and drew up a design for the 100 metric ton thrust engine for his space plane, now in the guise of an intercontinental rocket bomber. But the RLM never gave

Sänger adequate resources for the high-stakes rocket business and terminated his program in 1942.[26]

Lack of documentation makes it impossible to know when the Technical Office decided to make Sänger's institute into a secret competitor with the army. It could have been at the outset, but it may be relevant that the architect of the interservice alliance, Development Division Chief von Richthofen, left in November 1936 to become chief-of-staff of the Luftwaffe's Condor Legion, which was fighting for Franco in the Spanish Civil War. He asked for reassignment in part because of disagreements with Ernst Udet, the famous World War I fighter ace, whom Göring had cavalierly appointed to head the office in June 1936, even though he knew Udet to be a poor administrator. The major expenditure on Sänger's facility at Trauen could not have been made without Udet's approval, and it would have been consistent with Göring's desire to assert independence from the army.[27]

Shortly after the Air Ministry brought Sänger to Germany as a long-term investment, it also began to finance Walter's hydrogen peroxide rocket development, in the hope of more immediate results. In March 1936 Walter notified Ordnance that he no longer needed consultation because he had received from the RLM "a number of larger contracts for the development of hydrogen peroxide rocket devices, aerial torpedoes, jet reaction motors [ramjets?] and take-off-assist devices based on the catalytic decomposition of hydrogen peroxide." These contracts would finance the construction of a rocket test stand at Kiel as well, making the use of Kummersdorf facilities unnecessary.[28]

For military use in the field, hydrogen peroxide (H_2O_2) had a number of advantages over liquid oxygen. The latter cryogenic liquid, with a boiling point of −183°C (−297°F), is difficult to handle and hard to store for long periods; any aircraft or weapon could only be fueled immediately before use. Peroxide in high concentrations (80 percent or more) was not easy to handle either, because of its tendency to explode when in contact with organic contaminants. But it could be stored at normal temperatures, and Walter, together with a Munich chemical firm, had developed a system for producing and handling it. He could also offer two different engine types: "hot" and "cold." In the "cold" version, the inherently unstable peroxide was run over or mixed with a catalyst, often calcium or sodium permanganate, and decomposed into super-heated steam and oxygen. He demonstrated just such a system to representatives from the army, Heinkel, and the Luftwaffe, including von Richthofen, on 30 June–1 July 1936 (not without problems, one might add; erratic decomposition of the peroxide produced small explosions). The "hot" engine would be longer in coming; it burned the free oxygen in the catalyzed peroxide with a hydrocarbon fuel, producing more thrust. Fuel efficiency would be improved too, although hydrogen peroxide would always be a markedly inferior oxidizer to liquid oxygen.[29]

Attracted by peroxide's flexibility and potential, the Air Ministry began taking an intense interest in Walter no later than December 1935; the first contract came from the DVL, which wanted a small rocket motor for mounting on an aircraft wingtip for roll tests.[30] During 1936 the RLM rapidly turned Walter's development into a parallel program with von Braun's liquid-oxygen/alcohol project at Kummersdorf. The Development Division decided sometime in 1936 or early 1937 to install a Walter motor in another He 112, while both it and the Research Division were interested in assisted-takeoff systems for heavily loaded airplanes. Eventually hydrogen peroxide would become the dominant rocket propellant in the Luftwaffe, freeing that service almost completely from dependence on army technology.

THE FIRST ROCKET-ASSISTED FLIGHTS

While Walter's engines began to interest the RLM more and more, the Ordnance liquid-oxygen/alcohol project was still the primary rocket-aircraft propulsion program in 1936. Engine tests on the Junkers Junior began early in the year. In April von Braun wrote to the Research Division noting that a number of test firings had already been made, but the 300 kg thrust engine needed to be redesigned, and it shifted the airplane's center of gravity too far back. Plans to fly the Junior were then canceled following numerous explosions and burnthroughs of the new lightweight engine design. Many additional changes were needed, and the experiments lasted until at least August 1936.[31]

The Junior ground tests primarily became a pathfinder program for the He 112 project, which was funded by Development Division. During 1936 Kummersdorf designed, constructed, and test-fired the new 1000 kg thrust engines. Toward the end of the year, the von Braun group installed one in an He 112 rear fuselage, but there were still explosions and "hard starts" caused by delayed ignition. At least one fuselage was wrecked and replaced. As a result, the ignition system was changed to a small flame in the middle of the injector. In February 1937, von Braun reported that "tests with the He 112 partial fuselage are now [proceeding] without setbacks. So far 20 tests have been made."[32]

The time had come to install an engine in the first flight aircraft. The Luftwaffe or Heinkel provided the He 112 V4, the fourth prototype. Von Braun reported in February that the "first burn tests with the He 112 V4 should begin in the coming week." At the next monthly meeting, on 1 March, he noted that Erich Warsitz from the main Luftwaffe test facility at Rechlin had been named as test pilot.[33]

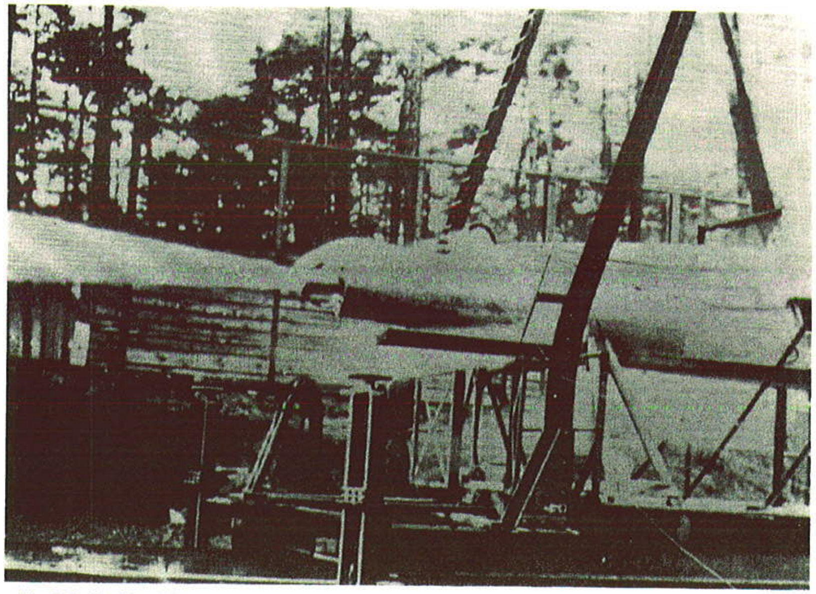

Fig. 9.2. An He 112 rear fuselage with a liquid-oxygen/alcohol rocket engine is tested at Kummersdorf, 1936–37. Courtesy Ernst-Karl Heinkel

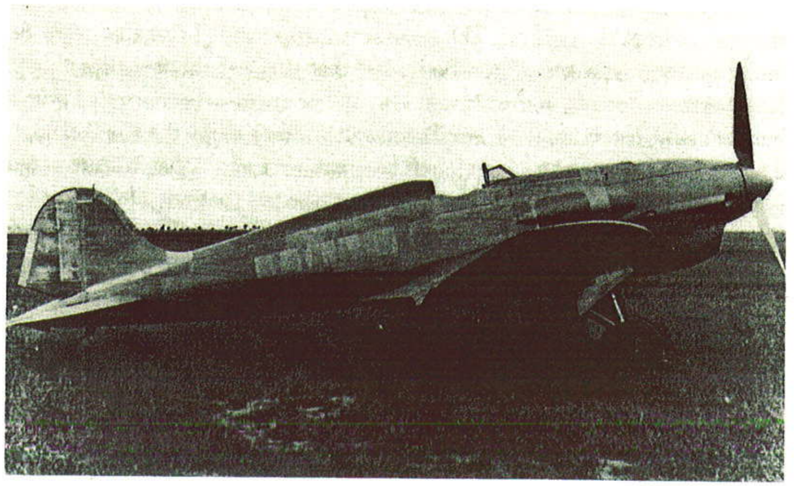

Fig. 9.3. The He 112 V4 aircraft immediately after completion at the Heinkel factory, probably in early 1936. Courtesy National Air and Space Museum, 72-8494

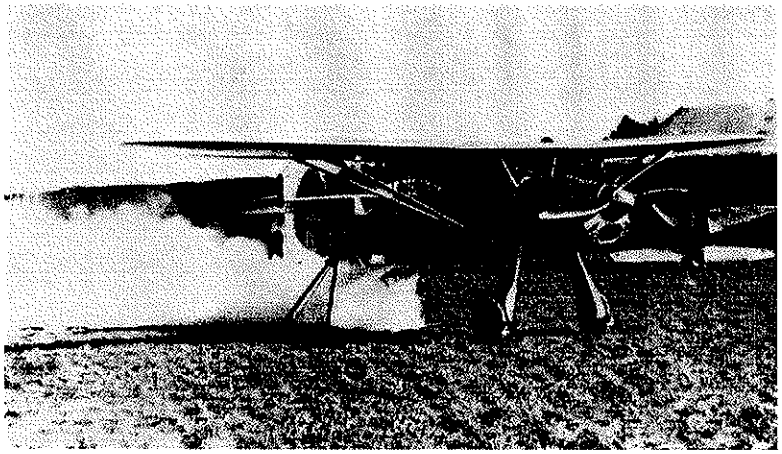

Fig. 9.4. The Focke-Wulf Fw 56 with a small Walter motor being tested at Neuhardenberg in the spring of 1937. Courtesy Public Record Office, ~~London~~ Kew

The successful static tests notwithstanding, the Ordnance group did not have much confidence in the engine. To fit a rocket to a manned airplane meant that the thrust had to be throttleable and the controls simple. But the system was still tricky and hard starts were always a possibility. When Warsitz first came to Kummersdorf, he stood beside the aircraft and watched as von Braun ignited the engine from the cockpit. The noise was ear-splitting. Later that night he found out from von Braun in a Berlin bar that this was the first time that it had ever been done from the aircraft. Usually the engine was controlled from a bunker many meters away, but von Braun and Walter Künzel, the Heinkel engineer responsible for the rocket-aircraft program, were afraid that Warsitz would never get in the cockpit if he observed the engine test that way![34]

While the He 112 V4 was being prepared for flight, the Walter "cold" hydrogen peroxide program was rapidly catching up. In fact, the Luftwaffe's first rocket-assisted flight was made with such an engine in January or February 1937. Watched by Technical Office Chief Ernst Udet, a Heinkel He 72 Kadett biplane trainer owned by the DVL was boosted by a Walter motor of about 130 kg thrust. According to Hellmuth Walter, Udet himself piloted the third flight. Beginning in April, the RLM planned a concentrated, highly secret test program at the isolated Neuhardenberg airfield, east of Berlin (Peenemünde-West was not yet ready). In addition to the He 112 V4, there was a Focke-Wulf Fw 56 with a Heinkel-installed Walter engine; an He 111 two-engine bomber with the first Walter takeoff-assist rockets designed to be dropped off and reused; and an He 72, probably with a smaller Kummersdorf liquid-oxygen/alcohol engine. Thirty flights were made with this aircraft. The latter project was likely dropped, and virtually nothing is known about the Walter experiments, but there were static tests of the Fw 56.[35]

After numerous delays and twenty-eight static tests and flights under normal engine power, the He 112 was finally ready on 3 June 1937. With Pauls, von Braun, and Künzel as witnesses, Warsitz for the first time tested the ignition system in the air. He started the ignition flame and then attempted to turn it off. Since it would not go out, he ignited the engine at half-power to prevent overheating. The acceleration was mild, and after ten seconds he stopped it again. But Warsitz soon, in the words of the official report, "noticed a strong acrid odor of burning rubber and paint and clearly perceptible hot gases flowed under the pilot's seat." He looked back to see the tail on fire! Since he was very low, he decided on an immediate belly landing. Damage was significant. An unanticipated region of low aerodynamic pressure around the tail had sucked alcohol fumes back into the fuselage, where they were ignited by heating or the ignition flame.[36]

The aircraft had to be sent back to the Heinkel works for repairs and modifications, with a target date for completion of 15 July. The rocket engine also needed a number of technical improvements to prevent a reoccurrence of the accident. For secrecy reasons, Ordnance at first insisted that the engine be reinstalled at Peenemünde-East but eventually relented and allowed it to be done in a closed building at Marienehe. Warsitz flew the He 112 V4 at Neuhardenberg later in the year, but no records of these flights have yet come to light.[37]

In spite of this success, the safety of the V4's nitrogen-pressurized tankage system was doubtful, so the RLM, Ordnance, and Heinkel decided to rebuild the aircraft. The propellants would instead be pumped, using a turbopump powered by catalyzed hydrogen peroxide from a "steam generator." The Ordnance rocket group had begun developing turbopumps in 1935, because of the need for them in large rocket engines, and had contracted with Hellmuth Walter for a steam generator in spring 1936. The He 112 V4 system was to be derived from the preliminary design for a Heinkel pure rocket aircraft, as well as from the turbopump/steam generator in the Walter-engined version of the He 112. Again, no concrete data is available, but Warsitz piloted the He 112 V3 before the end of 1937. Flights continued into 1938, culminating in takeoffs solely under "cold" hydrogen peroxide rocket power, with the piston engine turned off. The V3's successes and technical problems with Ordnance's system, in conjunction with the RLM's policy of fostering an independent rocket capability, no doubt strengthened its growing preference for hydrogen peroxide.[38]

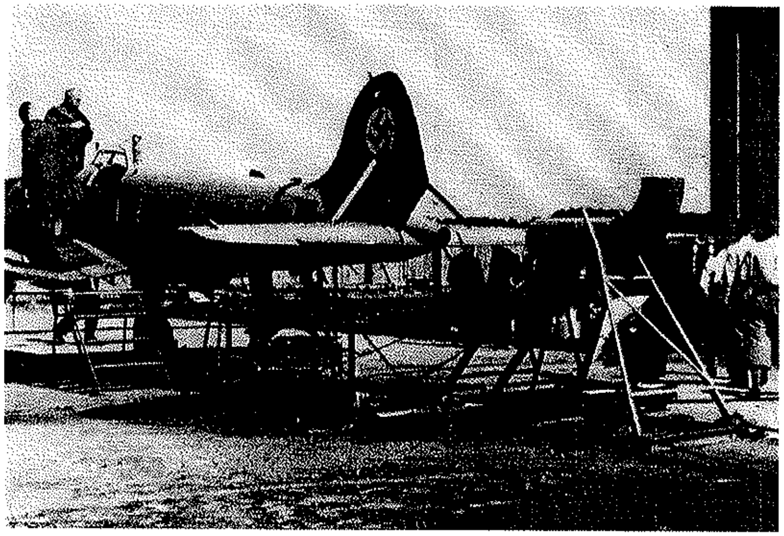

Fig. 9.5. The He 112 V3 at Neuhardenberg or Peenemünde-West, 1937–38. Courtesy Public Record Office, ~~London~~ Kew

THE HE 176

With the completion in the fall of 1937 of successful rocket-assisted flights, the RLM was finally ready to approve the pure rocket aircraft. In October 1937 it assigned the designation He 176 to the Heinkel company's Project "P 1033," a concept on the drawing boards since about December 1936.[39] Ignoring the RLM's interest in a rocket interceptor—a decision that would later be fateful—Ernst Heinkel and his designers, Walter and Siegfried Günter, together with Erich Warsitz, laid out the He 176 with one purpose in mind: speed. They were enthralled with the idea of creating the world's fastest aircraft and saw that the rocket plane might even put the magic number of 1,000 km/h (621 mph) in their grasp. At the time, the world's record barely exceeded 700 km/h. To save weight, the He 176 was tiny: it had a wingspan of about 5 m (16.4 ft), a length of about 6 m (19.7 ft), and a total loaded weight of under two tons. In accordance with the aerodynamic knowledge of the time, the wings were thin, but not swept back. Their total area of only 5.5 square meters meant very high wing loading, and thus a high landing and stall speed. As a result, the He 176 was tricky to fly and difficult to glide if the propellants ran out, which was not unlikely given that there was only enough to last two minutes. Finally, the cockpit

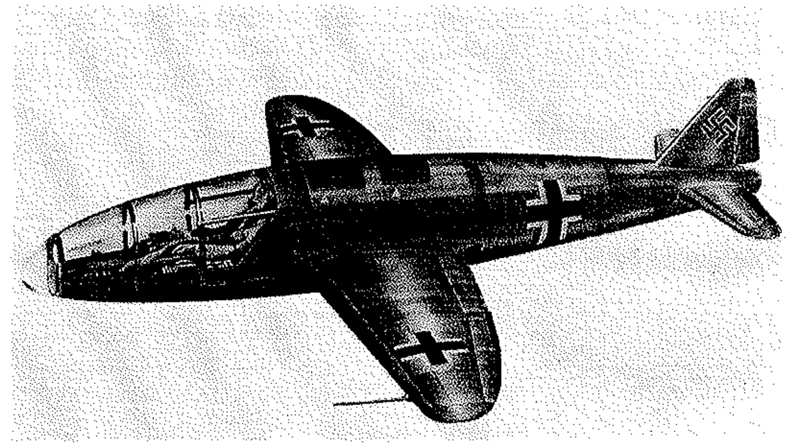

Fig. 9.6. A post-1945 artist's conception of the He 176 in flight. Courtesy Deutsches Museum

was so tight, it was literally designed to fit one man: Erich Warsitz. The He 176 would in effect be his personal rocket plane.[40]

Like the He 112, the He 176 would also receive two different rocket engines. Heinkel and the RLM decided no later than late 1937 that the first aircraft, the V1, would have a 600 kg thrust "cold" Walter motor, while the second would get the more powerful and efficient 1,000 kg, turbopump-driven, liquid-oxygen/alcohol engine similar to the one to be installed in the He 112 V4. Yet the He 176's small size was such that "the machine would already reach very high velocities in horizontal flight at a thrust of 40 to 100 kg." At an 11 January 1938 meeting, Ordnance, Heinkel, and the RLM decided to size the liquid-oxygen/alcohol engine for a thrust level of 750 kg (later reduced to 725 kg), with a capacity for the pilot to boost it to 1,000 kg for takeoff. Wernher von Braun's group also hoped to double combustion chamber pressure to 25 atm, further increasing fuel efficiency. Cooling problems, however, thwarted this plan, and the growing burdens of the army missile program kept the aircraft projects undermanned in Peenemünde-East and Kummersdorf. Ordnance promised the re-engined He 112 V4 would be ready in mid-March 1938, but technical problems postponed its return to Peenemünde-West until June 1939. The motor for the He 176 lagged even more, which must have further increased RLM skepticism about Ordnance's technology.[41]

The technical problems in fitting the liquid-oxygen/alcohol system to the little rocket plane were not confined to engine operation. From the outset, the engine mass in the tail was problematic because of its impact on the He 176's center of gravity. In early 1938 Heinkel specified a weight of only 14 kg, including the fuel circulating in the cooling jacket around the combustion chamber. Moreover, in August 1938 the Peenemünde-East engineer in charge stated: "The very difficult spatial relationships in the small machine make it necessary to divide the propellants among many tanks. For oxygen there are 3 tanks in a row one behind the other." The fuel was also divided between a fuselage tank and two in the wings—a very advanced design in which the water alcohol was contained inside the sealed wing structure. The multiple liquid oxygen tanks were particularly inopportune, because they increased warming and thus propellant evaporation loss. A small hydrogen peroxide tank was needed as well to power the steam-generator/turbopump. In truth, Ordnance's propulsion system was poorly suited to the tiny craft, which along with the He 176's marginal safety, brings into question the very design chosen by Heinkel and the Günter twins. By spring 1939 the Ordnance engine was postponed to the now projected V3 and V4 aircraft, which were to have one unified liquid oxygen tank. The He 176 V2 would receive a Walter motor.[42]

Little affected by these problems, Walter Künzel's ultrasecret "Special Development" unit at Heinkel proceeded rapidly with the construction of the V1 in 1938. In order to verify calculations of its aerodynamic qualities, the RLM paid for V1 testing from 9 to 13 July in the large windtunnel at the Aerodynamic Research Establishment in Göttingen. Meanwhile, Heinkel and Peenemünde-West began ground and air-drop tests of the separable cockpit section, which the designers had included because the He 176's anticipated high speed would make it impossible for Warsitz to make a traditional bail-out. In principle, Warsitz would fire explosive bolts and the cockpit would be separated by compressed air. The nose would be slowed by its own parachute until it reached a velocity at which he could jump out and descend on his parachute. But there were numerous problems with both the separation mechanisms and the cockpit parachute, which led to the addition of another 12 cm section behind the cockpit for a larger parachute and an inflation mechanism. The whole system was ultimately of little use, because it could only be activated above 6,000 m (20,000 ft).[43]

In late summer and fall 1938, the He 176 V1 underwent its first tow and taxi tests at Peenemünde-West.[44] It is immediately obvious that the V1 does not live up to its romantic postwar reconstructions. Most notably, it had an open cockpit and fixed landing gear, stop-gap measures likely undertaken by the Heinkel designers to accelerate the date of the first flight. (A flush canopy was available for flight tests.) The He 178 V1, the first turbojet aircraft, which was constructed in the same building, had the same features, reflecting Ernst Heinkel's desire to

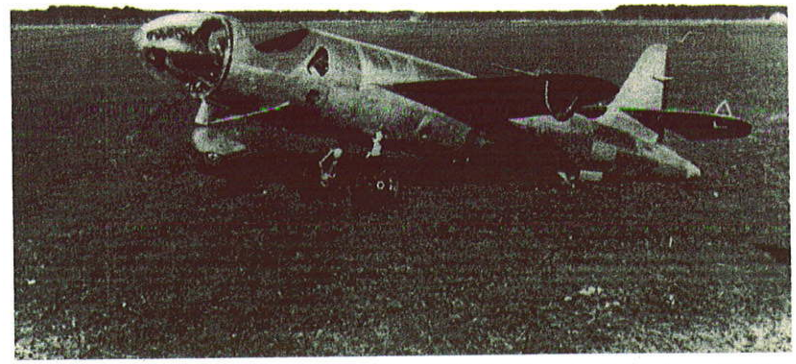

Fig. 9.7. The He 176 V1 at Peenemünde-West, 1938–39. Courtesy Public Record Office, ~~London~~ Kew

get that airplane in the air as soon as possible in order to demonstrate the concept and establish a first. For the He 176, the plan was undoubtedly to have retractable gear and the jettisonable cockpit section on the V2. As for the V1's peculiar stance—resting on a tail skid even though it had a nose wheel—the weight distribution of the tiny craft was so sensitive that when Warsitz climbed in, he tipped it forward![45]

Because the wing design had not permitted retracting the main gear into the wings, those two wheels were only separated by the width of the fuselage: 80 cm (31.5"). The effect of this astonishingly small wheeltrack was immediately visible during the first tow tests behind a powerful car. Mole hills and other imperfections on the Peenemünde-West grass airfield caused the V1 to bang its wingtips on the ground; eventually bumpers were installed to prevent further damage. The tow test showed other problems, notably that the rudder was completely ineffective at low speeds; at some point a jet vane was installed in the rocket exhaust that activated when the rudder went hard over. Since the tow tests were not very useful, Warsitz began to make taxi tests with short bursts from the hydrogen peroxide engine in fall 1938. These revealed propulsion and stability deficiencies that led to the decision to send the aircraft back to Heinkel during the winter for modifications, ending hopes that it would fly in 1938.[46]

In March 1939, the He 176 V1 returned to Peenemünde. Warsitz soon began to take short hops of tens of meters but found that the existing runway was

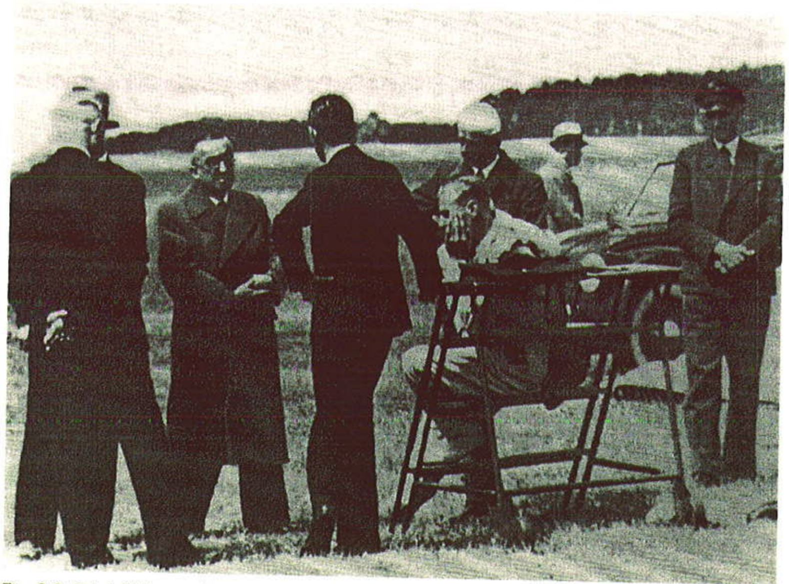

Fig. 9.8. Erich Warsitz (in white protective suit) sits with his face in his hand immediately after Gen. Ernst Udet forbade further flight tests of the He 176 V1. Third from the left is Ernst Heinkel. Courtesy Ernst-Karl Heinkel

Fig. 9.9. The only He 176 flight photo discovered so far. Whether this was a takeoff during a short hop or an actual flight is unknown. Courtesy Public Record Office

Fig. 9.10. Warsitz talks to Erhard Milch before or after a flight of the He 176 in June–July 1939. Courtesy Ernst-Karl Heinkel

too short for a full takeoff. Peenemünde-West hurriedly had to build extensions at either end. In May he was finally ready to give a demonstration to Ernst Udet and Göring's number-two man, State Secretary Erhard Milch. As soon as Udet saw the aircraft, Warsitz asserts, he exclaimed: "*Mensch*, those aren't wings, those are running boards! And you want to fly with that?" And after watching a short hop with a rather bad landing, Udet forbade Warsitz to fly the He 176 again, saying: "Every successful landing in that thing is a crash that miscarries." Warsitz allegedly flew to Berlin soon after and got Udet to lift the prohibition.[47]

After more test hops, Warsitz was finally ready on 15 June to make the first real flight. Accelerating very rapidly, Warsitz hit a new molehill and banged his aircraft's left wingtip bumper on the ground, diverting its takeoff roll to the left. Barely missing the trees, he turned and made a flight down the channel between the island and the mainland, circling back to the airfield. Warsitz claims that he exceeded 700 km/h (435 mph), but this is difficult to believe given the fixed landing gear and short flight duration. Fuel and endurance were so short, and the gliding characteristics of the airplane so doubtful, that he put the He 176 back down after only fifty seconds in the air. About 20 and 21 June, he repeated this hair-raising flight a couple more times, including once for Milch, Udet, and Heinkel.[48]

The He 176 flew for the very last time on 3 July 1939. In the hope of winning better industrial priorities for the Luftwaffe, Göring ordered that a demonstration of the latest technology be staged for Hitler at the main test center

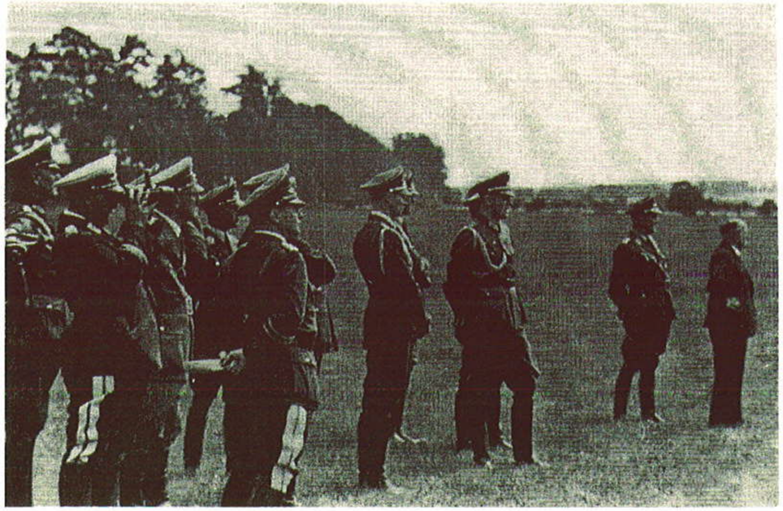

Fig. 9.11. Adolph Hitler (third from left) witnesses the He 176 demonstration flight near Rechlin on 3 July 1939. At far left is Gen. Wilhelm Keitel, armed forces chief of staff; next to him is Field Marshal Hermann Göring, Luftwaffe commander in chief. Courtesy Ernst-Karl Heinkel

of Rechlin. Among other aircraft, the Führer saw the not-yet-flown, turbojet-powered Heinkel He 178 V1. Ernst Heinkel and the engine's inventor, Hans von Ohain, provided explanations. The climax of Hitler's visit was a flight of the He 176 from a field a few kilometers away. After a successful takeoff and quick circuit, Warsitz narrowly avoided a crash during the landing when the Walter motor quit at low altitude. He barely restarted it in time. Fortunately, this near disaster was imperceptible to nonexpert observers; an impressed Hitler ordered that Warsitz receive a prize of 20,000 marks. Not surprisingly, neither the RLM, Warsitz, nor Heinkel had any desire to see the V1 fly again. It was too risky, the attempt at record-breaking speed could only be made with the V2, and it was time to flight test the He 178.[49]

END OF THE FIRST ROCKET AIRCRAFT PROGRAM

The end for the He 176 came on 12 September 1939. In reordering priorities after Germany's unprovoked attack on Poland and the consequent, somewhat unexpected outbreak of World War II, Ernst Udet canceled the rocket plane, along with numerous other projects. Construction of the V2 through V4 airframes was abandoned. For unknown reasons, the contract with the army for the He 176's turbopump-driven, liquid-oxygen/alcohol engine continued for

a few more months. Moreover, the He 112 V4 began flying again as a testbed for a similar engine in summer-fall 1939. Nonetheless, the interservice rocket-aircraft program was effectively dead. That was confirmed on 18 June 1940, when the He 112 V4 crashed at Peenemünde during its twenty-fifth flight with the redesigned engine. Another tail fire had severed the control linkages; the airplane dove into the ground, killing the pilot. Eventually the last vestige of Heinkel's rocket-aircraft work, the He 176 V1, was crated and sent to the Berlin Air Museum, where it was destroyed in an air raid in 1943 or 1944.[50]

Yet even before the He 176 and interservice programs, a transition to a second rocket-aircraft program was already underway. The RLM, and Udet in particular, were skeptical of not only the He 176's safety but also its usefulness. Ernst Heinkel and his designers, supported by Erich Warsitz, had tried to create an experimental record-breaking aircraft, the Luftwaffe's interest in a rocket interceptor notwithstanding. Heinkel's quest for fame and firsts had not been his sole motivation; he was also obsessed with protecting what was left of his autonomy against a ministry that had a monopoly on all domestic aircraft purchases, civil and military. Heinkel's decision to proceed with an aircraft that was so narrowly specialized—and so questionably designed—contributed, however, to a growing rift with the Air Ministry that would trouble him to the end of the Third Reich. Since no documents are available, it is impossible to pin down when the RLM began to disagree with Heinkel over the He 176's military impracticality, but Warsitz recalls that arguments with RLM officials caused weeks of delay. Warsitz also claims that he had to fight an order in mid-1938 not to fly the aircraft because it was unsafe. By the end of that year, the ministry had created a second rocket interceptor program at Messerschmitt.[51]

That program, which led to the Me 163 Komet, had its origin in fall 1937, when two members of the Research Division approached Alexander Lippisch, a well-known designer of unorthodox delta-wing gliders. They asked him to build an aircraft for a new, secret propulsion system, which Lippisch guessed immediately because he had put solid-fuel rockets on gliders during the late Weimar spaceflight fad. Sometime in 1938, Lippisch traveled to Rostock to discuss his project with Heinkel, the only airframe company with explicit knowledge of the rocket-aircraft program. It also possessed the special secure building for the project. As Lippisch later recalls, the meeting did not go well, because he felt that Heinkel's designers viewed him as a rival. Based in south-central Germany, Lippisch could also see potential coordination problems because of distance and different design philosophies. He had good relations with the Messerschmitt company in Bavaria, and Hans Antz, who took over responsibility in the RLM for high-speed airframes in October 1938, felt that creating a second, competing "special aircraft" group would be a good idea. Moreover, Messerschmitt had single-seater expertise. While Antz was not hostile to Heinkel, he saw that the

He 176 was purely experimental and would not lead directly to a rocket interceptor. On 2 January 1939, through Air Ministry mediation, Lippisch's group became "Department L" at the Messerschmitt factory in Augsburg.[52]

Only after the unhappy end of Heinkel's involvement in rocket aircraft in 1939–40 did the Lippisch/Messerschmitt group become *the* Luftwaffe project in this area. But in the meantime, the rocket interceptor concept had itself been somewhat eclipsed by a profound transformation in aircraft reaction propulsion: the "turbojet revolution." Knowing of Ernst Heinkel's fascination with speed, Hans von Ohain contacted him in March 1936 through his doctoral adviser in order to receive support for his turbojet idea. Heinkel brought him to Rostock-Marienehe and begun funding his experiments privately, not telling the RLM. Von Ohain, for his part, only had vague intimations of the rocket work going on simultaneously at the plant. After he successfully demonstrated his first primitive, bench-model turbojet in spring 1937, Ernst Heinkel and his designers saw that they indeed had a potentially revolutionary propulsion system in their hands. But to receive priorities for materials in the tightly regulated Nazi economy, Heinkel revealed the project to the RLM no later than December. In spring 1938, when Uvo Pauls left Berlin to take over Peenemünde-West, he was replaced as desk officer of "Special Engines" by an energetic, highly trained young engineer, Hans Mauch. Mauch in turn attracted another well-trained engineer, Helmut Schelp from the Research Division, to assist him. The two immediately grasped the importance of the turbojet and set out to interest aero-engine manufacturers in the technology.[53]

I will not repeat the details of the "turbojet revolution" in Germany here. Suffice it to say that the RLM in the person of Mauch, Schelp, and their ally in airframes, Antz, did not neglect turbojet technology, as Ernst Heinkel asserted after the war. Quite the opposite, in fact, but the RLM officials were skeptical of his airframe company's ability to mass produce engines—something Heinkel naturally resented. They may also have been irritated by his independent streak. After some effort, Mauch and Schelp managed to interest Junkers, BMW, and other companies in starting turbojet programs, while Antz encouraged Messerschmitt to begin a jet fighter design in addition to its rocket plane work. But they certainly had no intention of discouraging Heinkel—and on 27 August 1939, five days before the German assault on Poland, Warsitz flew the He 178 V1. Two weeks later, when Udet canceled the He 176 and many other projects, his comment on the He 178 was: "Work on single-seaters with turbojet engines must be pushed forward with all speed, so that an operational aircraft can be created as soon as possible." Notwithstanding Heinkel's later assertions that Udet and his subordinates took little interest in the He 178, jets clearly had high priority from the Luftwaffe from the beginning of the war.[54]

CONCLUSIONS

Why was the German Air Ministry so open to the turbojet idea in 1938–39, just as it was to the rocket in 1935? In both cases, personalities played important roles—in 1935, von Richthofen, in 1938–39, Mauch, Schelp, and Antz. Throughout the period one can also see the influence of general factors: notably, the absence of an entrenched establishment in the Luftwaffe, the high level of scientific and engineering competence in the German aeronautical community, and the technological and ideological enthusiasm of engineers, industrialists, and officers who wished to make Hitler's Reich quickly superior to the other powers.

Yet there is little doubt that the Luftwaffe's first foray into reaction-propulsion technology also laid the groundwork for the second. When Mauch, Schelp, and Antz came into their positions in 1938, the Air Ministry already had a considerably investment in that technology, in small part through Paul Schmidt's ongoing pulsejet research and Eugen Sänger's rocket institute, but above all through the rocket-aircraft and takeoff-assist programs increasingly dominated by Hellmuth Walter's technology. No other air force in the world had so much experience with, and interest in, rocketry and other forms of reaction propulsion. The only partial exception was the Soviet air force, but Stalin's purges derailed the USSR's rocket programs in 1938. In Britain and the United States, advocates of rocket and turbojet propulsion only began to get support from the services around that time.[55]

If the history of the Luftwaffe's quest for high-speed flight by rocket plane sheds light on the origins of the "turbojet revolution" in Germany, it also illuminates the relations between aircraft manufacturers and the Air Ministry. Heinkel's desire to protect his independence as a designer and industrialist clashed with the RLM's desire for total control over all German aviation, military and civilian. While the so-called National Socialist regime was largely capitalist in its economic base, the Nazis did not hesitate to nationalize firms or create new government-owned firms if private capital was not amenable to their aggressive aims. In the case of the aircraft industry, Hitler's regime made a frightening example of Hugo Junkers in 1933, when he was put under house arrest and forced to relinquish ownership of his firms because of his democratic and pacifist views. He died a broken man two years later. Ernst Heinkel, whose politics were certainly more congenial to the Nazis, must nevertheless have been mindful of that ultimate threat. Yet, as the He 176 and turbojet/He 178 programs show, he did try to retain as much technical and managerial control over them as was feasible—in the former case, designing the airplane for record-breaking speed rather than military use, in the latter case, attempting to finance the radical new engine technology alone. This strategy added to RLM's growing irritation with him after 1938, which in turn contributed to his ultimate loss of the contracts for operational rocket and jet fighters to Willi Messerschmitt.

Finally, the history of the first German rocket-aircraft program illuminates the origins of many myths about the Luftwaffe's pioneering efforts, notably those that derive from Heinkel's memoirs. He was understandably bitter about the RLM favoring Messerschmitt, although he had pioneered both technologies. He was further embittered about his fight with the Ministry over the right to mass produce jet engines after 1939; although it eventually allowed him to buy the Stuttgart aero-engine firm of Hirth, none of his engine types got beyond the development stage. During the war, there were recriminations about the failure of the He 177 heavy bomber project as well. As a result, Heinkel unconsciously rewrote the history of the early years of rocket and jet aircraft to minimize the competence and significance of the Air Ministry. In fact, he eliminated the RLM from the origins of rocket aircraft altogether, even though it had been the driving force from the outset, and he cited Udet's dismissive comments about the He 176 V1 as evidence for the Ministry's continuing short-sightedness. As for the turbojet, after 1945 he labeled the RLM as bumbling and slow, and his views fit well with those of others, like Gen. Adolf Galland, who claimed that the Ministry and Hitler were responsible for jet aircraft allegedly appearing "too late" to alter the course of the war.[56] Although there is no doubt that the RLM's Technical Office slowly became dysfunctional after Udet took over in 1936, the reality behind these myths is an important lesson for aerospace historians, who have too often accepted memoirs and interviews uncritically, while neglecting primary research.

Despite the justified questions about Heinkel's book, and about his committed service to an evil regime, there is no doubt that his imagination and energy contributed much to the achievement of the two historic firsts by the He 176 and 178. Along with Hans von Ohain, Helmuth Walther, Wernher von Braun, and many others, Heinkel played a critical role in ushering in a new era of aeropropulsion and high-speed flight. Of that place in history, at least, he cannot be deprived.

NOTES

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1. A few Germans made flights in gliders boosted by commercial solid rockets in late Weimar; see Frank H. Winter, "1928–1929 Forerunners of the Shuttle: The 'Von Opel' Flights," *Spaceflight* 21 (Feb. 1979): 75–83, 92. The He 176 was, however, the first aircraft designed from the outset to be powered exclusively by a rocket engine. See the valuable article by Volker Koos, "Heinkel He 176—Dichtung und Wahrheit," *Jet & Prop* No. 1 (1994): 17–21, and Botho Stüwe, *Peenemünde-West* (Esslingen: Bechtle, 1995), chap. 8. For a useful overview, see C. M. Ehresman, "Liquid Rocket Propulsion Applied to Manned Aircraft—In Historical Perspective," *Journal of the British Interplanetary Society* 46 (1993): 255–68.

2. Edward W. Constant II, *The Origins of the Turbojet Revolution* (Baltimore, Md.: Johns Hopkins University Press, 1980). Constant's term effectively describes the transformation even if one does not accept his Kuhnian model of technological change.

3. Ernst Heinkel, *Stürmisches Leben*, ed. Jürgen Thorwald (pseud. for Heinz Bongartz) (Stuttgart: Mundus, 1953); translated as *Stormy Life* (New York: Dutton, 1956). See chap. 12.

4. H. Dieter Köhler, *Ernst Heinkel—Pionier der Schnellflugzeuge* (Koblenz: Bernhard & Graefe, 1983), pp. 15–16, 177.

5. William Green and Frank Ziegler, "World's First Jets," *RAF Flying Review*, July 1954, pp. 17–19; J. R. Smith and Anthony L. Kay, *German Aircraft of the Second World War* (London: Putnam, 1972), pp. 262–63, 276–79, 290–92; Heinz Nowarra, *Heinkel und seine Flugzeuge* (Munich: J. F. Lehmanns, 1975), pp. 115–16, 118; Wolfgang Wagner, *Die ersten Strahlflugzeuge der Welt* (Koblenz: Bernhard & Graefe, 1989), pp. 46–47. In *Rocket Fighter* (New York: Ballantine, 1971), pp. 18–37, William Green takes a more differentiated approach to the RLM but still is dependent on Heinkel for the rocket aircraft program. Köhler's hagiographic but fairly scholarly biography is similar: *Ernst Heinkel*, pp. 150–63.

6. Constant, *Origins of the Turbojet Revolution*, pp. 198–207; Ralf Schabel, *Die Illusionen der Wunderwaffen* (Munich: R. Oldenbourg, 1994), pp. 37–44; Heinkel, *Stürmisches Leben*, pp. 448–52. Even Schlaifer's classic study of aero-engines in Robert Schlaifer and S. D. Heron, *Development of Aircraft Engines/Development of Aviation Fuels* (Boston: Graduate School of Business Administration, Harvard University, 1950), pp. 377–78, repeats Heinkel's rocket-aircraft myth. Heinkel's stories, conveyed through Allied interrogations, obviously were influential even before they were published in memoir form.

7. The Army side was treated in the memoirs of Gen. Walter Dornberger, *V-2* (New York: Viking, 1954), and Wernher von Braun (hereinafter WvB), "Reminiscences of German Rocketry," *Journal of the British Interplanetary Society* 15 (May–June 1956): 125–145, but in both cases so superficially as to have little impact on the acceptance of Heinkel's story.

8. See Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (New York: Free Press, 1995/Cambridge, Mass.: Harvard University Press, 1996), pp. 333–37, for a description. The FE (Fort Eustis) microfilm of Ordnance/Peenemünde records is at the National Air and Space Museum Archives Division (hereafter NASM), Garber Facility Bldg. 12. The key file on Army-Luftwaffe cooperation is FE746 on FE rolls 36–37; the original is now file RH8/v.1946 in the Bundesarchiv/Militärarchiv Freiburg (hereafter BA/MA).

9. Zanssen note, 20 May 1935, and marginal comment by "D." on von Horstig (Zanssen) to Wimmer, chief of RLM Tech. Office, 22 May 1935, in NASM, FE746; Baeumker/RLM/LC I to Becker, 10 Oct. 1934, in Imperial War Museum, MI 14/801(V). Technical Office Research Division was LC I, Development Division was LC II.

10. On the Air Ministry, see Edward L. Homze, *Arming the Luftwaffe* (Lincoln: University of Nebraska Press, 1976).

11. On German aerodynamics, see Constant, *Origins of the Turbojet Revolution*, pp. 152–60.

12. Schneider order on A-2 presentation, 15 Jan. 1935, in BA/MA, RH8/v. 1945; WvB, "Reminiscences," pp. 123–24.

13. Von Richtofen notes, 6 Feb. 1935, in National Archives (hereafter NA) microfilm publication

T-971, roll 73 (no frame numbers); von Richthofen to von Horstig, 6 Feb. 1935, Zanssen (WvB) report, 16 Feb. 1935, von Horstig (Zanssen) to von Richthofen, 19 Feb. 1935, and Junkers report of 18 Dec. 1934 in BA/MA, RH8/v. 1221; Harald Kunze, "Die Zusammenarbeit von Hugo Junkers und Johannes Winkler," *NTM* 24 (1987): 63–82.

14. Zanssen and WvB report, 26 Mar. 1935, on Schmidt visit, Becker (Zanssen) to RLM, 9 Apr. 1935, and WvB note to Zanssen, 30 June 1935, in Deutsches Museum Archives (hereinafter DM); P. Schmidt and F. Goslau contributions to Theodor Benecke and A. W. Quick, eds., *History of German Guided Missile Development* (Braunschweig: E. Appelhaus, 1957), pp. 375–418.

15. Walter to Becker, 15 Oct. 1934, in NASM, FE 724/b, and Walter to Reichswehr Ministry, 28 Oct. 1934, in NASM, FE 724/c; H. Walter article in Benecke and Quick, *History*, pp. 263–80. See also Hellmuth Walter, *Report on Rocket Power Plants Based on T-Substance* (translation of 1943 report), NACA Technical Memorandum No. 1170 (Washington: NACA, 1947); Walter, "Experience with the Application of Hydrogen Peroxide for Production of Power," *Jet Propulsion* 14 (May–June 1954): 166–71; Emil Kruska, "Das Walter-Verfahren, ein Verfahren zur Gewinnung von Antriebsenergie," *VDI-Zeitschrift* 97 (1955): 65–70, 271–77, 709–13, 823–29; and René Simard, "Hydrogen Peroxide as a Source of Power," *The Engineering Journal* (Canada) 31 (Apr. 1948): 219–25.

16. Walter to Becker, 15 Oct. 1934 (quote), in NASM, FE727/b; and Walter-Ordnance correspondence, 29 Nov. 1934–27 Mar. 1936, in NASM, FE727/b and /c; Walter and Irene Sänger-Bredt contributions in Benecke and Quick, *History*, pp. 263, 277–78, 326.

17. Constant, *Origins of the Turbojet Revolution*, pp. 178–204; Zanssen note, 20 May 1935, and Aktennotiz, 22 May 1935, in NASM, FE746.

18. Von Horstig (Zanssen) to Wimmer, 22 May 1935, in NASM, FE746.

19. WvB, "Stellungnahme . . . ," 27 June 1935, and von Horstig minutes of 27 June meeting in NASM, FE746.

20. Von Horstig minutes of 27 June 1935 meeting in NASM, FE746; von Richthofen notes, 27 May 1935, in NA, T-971/73.

21. Draft agreement, 2 Sep. 1935, WvB to Lorenz, 25 Oct. 1935, Kirchhoff to WvB, 10 Jan. 1936, Kirchhoff to DVL, 10 Jan. 1936, and WvB to Lorenz, 24 Apr. 1936, in NASM, FE746; WvB to von Horstig, 23 Nov. 1935, in NASM, FE727/a; Constant, *Origins of the Turbojet Revolution*, p. 203.

22. WvB minutes of 16 Oct. 1935 meeting, Heinkel works to WvB, 5 Oct. 1935, and WvB to Alpers/RLM/LC II, 14 Dec. 1935, in NASM, FE746. The Oct. 16 meeting must be the one that Heinkel, in *Stürmisches Leben*, pp. 448–50, places in November.

23. Neufeld, *Rocket and the Reich*, pp. 49–56; Stüwe, *Peenmünde-West*, p. 20.

24. Arthur Rudolph, oral history interview with Michael Neufeld, Hamburg, Germany, August 4, 1989, deposited in the NASM Department of Space History; Helmuth Trischler, *Luft und Raumfahrtforschung in Deutschland* (Frankfurt: Campus, 1992), pp. 208–19.

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26. Gartmann, *Men*, pp. 103–106; Eugen Sänger, "Arbeits-Kurzbericht der Abteilung Sänger 1936–1945," manuscript, July 1945, in American Institute of Physics, Samuel Goudsmit Papers; Sänger-Bredt, "Silver Bird," pp. 206–11; I. Sänger-Bredt and R. Engel, "The Development of Regeneratively Cooled Liquid Rocket Engines in Austria and Germany, 1926–1942," in *First Steps Toward Space*, ed. Frederick C. Durant III and George S. James (San Diego: Univelt, 1985), pp. 237–44; Trischler, *Luft- und Raumfahrtforschung*, pp. 219–20.

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28. Wa Prw 11 to von Horstig, 27 Mar. 1936, in NASM, FE724/b.

29. W. Riedel Aktennotiz, 5 July 1936, in NASM, FE 724/b; Elektrochemische Werke München AG, "Bericht für Herrn Prof. Dr. Krauch . . . ," 17 Mar. 1942, in NA, T-73/r. 84/fr. 3396669-73; Walter, "Development," in Benecke and Quick, eds., *History*, pp. 263–80; Walter, "Experience," pp. 166–67; Simard, "Hydrogen Peroxide."

30. Kruse/RLM to von Horstig, 23 Dec. 1935, in NASM, FE724/b; William Green, *Warplanes of the Third Reich* (Garden City, NY: Doubleday, 1972), p. 594.

31. WvB to Lorenz/RLM/LC I, 24 Apr. 1936, Tschirschwitz/DVL reports, 16 June and 19 Aug. 1936, in NASM, FE746; Walter Riedel, "Raketenentwicklung . . . ," (ms., 1950), Imperial War Museum, German Misc. Doc. 148, p. 35; Dornberger, *V-2*, p. 124.

32. RLM/LC II report, 18 Feb., on monthly meeting with Wa Prw D, and RLM minutes of visits to Heinkel, 16 Jan. and 16 Feb. 1937, in NASM, FE746; Heinkel, *Stürmisches Leben*, pp. 450–51, 455; Stüwe, *Peenemünde-West*, pp. 19, 25.

33. RLM/LC II reports, 18 Feb. and 1 Mar. 1937, on monthly meetings with Wa Prw D, in NASM, FE746. The V4 was not sent to Spain, as various secondary sources report; see "Aufstellung über He112," 31 Mar. 1937, Heinkel archives, Stuttgart, kindly supplied by Volker Koos. Stüwe, based on a 1952 Warsitz interview, states that the test pilot had been involved since December 1935. This is possible, but not supported by surviving Ordnance records. Stüwe makes numerous mistakes regarding the "He 112R" due to weak archival research: *Peenemünde-West*, pp. 13–26.

34. Warsitz quoted in Bob Ward, *Wernher von Braun Anekdotisch* (Esslingen: Bechtle, 1972). pp. 7–9; Stüwe, *Peenemünde-West*, pp. 16–17.

35. RLM/LC-Wa Prw D correspondence and minutes, 18 Feb.–3 May 1937, in NASM, FE746; W. Ahlborn, "Flugmessungen an einem Stück des Flugzeugmusters FW 56 mit Walter-Rückstoßgerät," Deutsche Luftfahrtforschung Forschungsbericht Nr. 1078 (1939), NASM, German-Japanese Air Technical Documents, r. 2017; H. Walter, *Report*, p. 1, "Experience," p. 166, and "Development," pp. 264, 270; Koos, "He 176," p. 20; Stüwe, *Peenemünde-West*, pp. 31–39; Heinkel, *Stürmisches Leben*, pp. 458–59.

36. Pauls, WvB, Künzel, Warsitz report, 3 June 1937, and LC II 2e report, 7 June 1937, in NASM, FE746; Dornberger, *V-2*, p. 125.

37. RLM/LC-Wa Prw D-Heinkel correspondence, 23 June–13 July 1937, in NASM, FE746; Heinkel, *Stürmisches Leben*, p. 457; Stüwe, *Peenemünde-West*, pp. 36–37.

38. Ordnance-RLM-Heinkel correspondence and minutes, 16 Jan. 1937–3 Jan. 1938; WvB to von Horstig, 23 Nov. 1935, in NASM, FE727/a; Ordnance-Walter correspondence, 1936, in NASM, FE724/b; Stüwe, Peenemünde-West, p. 39. Footage of He 112 V3 takeoffs can be found in the 1945 Royal Air Force film "Rocket Flight," NASM.

39. Letter from Volker Koos, 17 Apr. 1996. "P 1033" is first mentioned in the 18 Feb. 1937 minutes, "He 176" in the Heinkel minutes of a 23 Oct. 1937 meeting with WvB, both in NASM, FE746.

40. Köhler, *Ernst Heinkel*, pp. 22–23, 90–91, 153–56; Koos, "He 176," pp. 19–21; Stüwe, *Peenemünde-West*, pp. 150–57; Heinkel, *Stürmisches Leben*, pp. 460–62; Antz memorandum, 14 Oct. 1938, BA/MA, RL3/780.

41. Ordnance-RLM-Heinkel correspondence and minutes, 13 Dec. 1937–15 June 1939, in NASM, FE746 (quotation from 11 Jan. 1938; see esp. Dellmeier report of 2 Aug. 1938); Stüwe, *Peenemünde-West*, p. 188; Neufeld, *Rocket and the Reich*, chap. 3.

42. Ordnance-RLM-Heinkel corr. and minutes, 8 Dec. 1937–28 Apr. 1939 (quote from Dellmeier report of 2 Aug. 1938), in NASM, FE746. The Antz memorandum, 14 Oct. 1938, in BA/MA, RL3/780, lists He 176 V3 and V4 as Walter-engine craft, but Hertel (draft by Künzel) to WvB, 6 Mar.

1939, in FE746, discusses their redesign with unitary liquid-oxygen tanks, strongly implying that V3 would be the first Ordnance-engine aircraft.

43. Koos, "Heinkel He 176," pp. 19–20; Heinkel-AVA Göttingen-RLM correspondence, May–Aug. 1938, in DLR e.V., Göttingen, copies courtesy of Volker Koos; Stüwe, *Peenemünde-West*, pp. 156–62; Smith and Kay, *German Aircraft*, pp. 276–79.

44. It was found in a 1945 British report on hydrogen peroxide, ADM 199/2434, Public Record Office, Kew. Koos first published it in his 1994 article, "Heinkel He 176."

45. On the He 178, see Hans von Ohain in Joseph J. Ermenc, ed., *Interviews with German Contributors to Aviation History* (Westport, Conn.: Meckler, 1990), p. 37; Heinkel minutes of mid-July 1938 meeting, in Wagner, *Die ersten Strahlflugzeuge*, p. 17; J. Richard Smith and Eddie Creek, *Jet Planes of the Third Reich* (Boylston, Mass.: Monogram Aviation Publications, 1982), pp. 12–17.

46. Stüwe, *Peenemünde-West*, pp. 171–75, based on a 1952 Warsitz interview and a 1963 speech by Künzel, both in Warsitz's papers.

47. Ibid., pp. 175–77.

48. Ibid., pp. 177–82. Stüwe gives reasons why the traditional first flight date of 20 June is very probably wrong. See also Warsitz's 1959 account quoted in Köhler, *Ernst Heinkel*, pp. 158–59.

49. Stüwe, *Peenemünde-West*, pp. 182–88. See also Heinkel, *Stürmisches Leben*, pp. 468–72; von Ohain in Ermenc, ed., *Interviews*, pp. 42–44; von Ohain, telephone interview with author, 21 Feb. 1996.

50. Stüwe, *Peenemünde-West*, pp. 190–94; Udet order, 12 Sep. 1939, in BA/MA, RL3/1825; Udet order, 16 Nov. 1939, in BA/MA, RL3/352; Zanssen to Dornberger, 22 June 1940, Thiel to Pauls and Thiel to Dornberger, 18 July 1940, in NASM, FE746; Schabel, *Illusionen*, p. 53.

51. Stüwe, *Peenemünde-West*, pp. 162–63, 172–73; Smith and Kay, *German Aircraft*, pp. 278–79; Köhler, *Ernst Heinkel*, pp. 21–23, 132.

52. Lippisch in Ermenc. ed., *Interviews*, pp. 166–69; Antz memorandum, 14 Oct. 1938, BA/MA, RL3/780.

53. Constant, *Origins of the Turbojet Revolution*, pp. 194–201; Schabel, *Illusionen*, pp. 38–40; Hans von Ohain, "The Evolution and Future of Aeropropulsion Systems," in Walter J. Boyne and Donald S. Lopez, eds., *The Jet Age* (Washington, D.C.: NASM, 1979), pp. 25–46, here 30–34; von Ohain telephone interview; Köhler, *Ernst Heinkel*, pp. 163–69, 176; von Ohain and Schelp in Ermerc, ed., *Interviews*, pp. 5–42, 108–10.

54. Schabel, *Illusionen*, pp. 39–42, 51–54; Constant, *Origins of the Turbojet Revolution*, pp. 200, 204–207; Udet order, 12 Sep. 1939, in BA/MA, RL3/1825; Smith and Kay, *German Aircraft*, pp. 532–33; Heinkel, *Stürmisches Leben*, pp. 474–85.

55. Frank H. Winter, *Prelude to the Space Age* (Washington, D.C.: Smithsonian Institution Press, 1983), pp. 55–71; Constant, *Origins of the Turbojet Revolution*, pp. 190–92; Sir Frank Whittle, "The Birth of the Jet Engine in Britain," in Boyne and Lopez, *The Jet Age*, pp. 3–24, here 9–10; Clayton R. Koppes, *JPL and the American Space Program* (New Haven, Conn.: Yale University Press, 1982), pp. 8–10.

56. Schabel's *Illusionen der Wunderwaffen* is the most systematic attack yet on the persistent myths about the jets.

CHAPTER 10

Revolutionary Innovation and the Invisible Infrastructure

Making Royal Air Force Bomber Command Efficient, 1939–45

ROBIN HIGHAM

By the mid-1930s aviation had advanced to the point that many developments coalesced to create not only the visible signs that aviation had reached a real takeoff point but also the environment for success. These developments were not merely the visible progress in aerodynamics, engines, fuels, reliability, and economy of operation for the airlines and of range and firepower for air forces, but in the hidden infrastructure, from metallurgy to testing to operational support.

Progress to the mid-1930s could be seen in the use of all-metal construction, itself made really feasible by the development of the aluminum alloy S2024 and flush riveting, by the RAF's testing of engines to raise reliability from the meager 2 hours and 44 minutes of 1918 to some 1,700 hours by 1929, by the development of rated fuels and cast-block engines, by the appearance of the variable-pitch and constant-speed propellers, by retractable undercarriages, hydraulic brakes, flaps, and other ancillary systems, as well as by the training of fitters and riggers (mechanics) as well as pilots in rigorous schools, to mention but some of the important evidence.

But it was really the failure in 1934 of the disarmament talks, followed by rearmament and then war, that cut the purse strings and allowed air force innovation to flourish. This other side of the visible progress and revolutions that took place between 1934 and 1945 has been neglected because it has been taken for granted or overlooked. None of the revolutionary rate of innovation in this critical decade could have been possible without the invisible infrastructure that enabled innovation to be converted into functional reality. The invisible infrastructure itself was an offspring of the quiet progress of the 1918–34 period, as