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## FORUM

*THE DEVELOPMENT OF THE FLYING WING*

Ralph L. Schwader

The quest for the perfect and efficient airplane has been an ongoing challenge throughout most of the 20th century. Man's struggle to understand the physical forces of aerodynamics has been costly not only in terms of economics but also in human lives. In the developmental and testing stages, aircraft designers and builders have always had to deal with the basic forces of lift, weight, thrust, and drag. The politics of the world also have had a major influence on the development of new aircraft, be it for profit or for war. Aircraft designers and manufacturers are continually searching for ways to improve aircraft for speed, range, weight-carrying capacity, and many other characteristics. The flying wing was conceived, developed, and has evolved for many of the same reasons in man's search for perfection in flying machines.

The idea of a true flying-wing aircraft originated in Europe. Experiments by Otto Lilienthal, a German considered the father of the glider, probably had an impact on the development of the flying wing (Von Karman, 1967). Possibly the first true flying wing, which was shaped like an elliptical seed, was designed and flown by Czechoslovakian designer Igo Etrich in 1909. He abandoned the true wing concept and added a tail for stability.

Most of the European planes developed in this era were not true wing aircraft. They also had flimsy vertical fins and horizontal stabilizers. But there were exceptions. The British in 1910 developed the Dunne D.6 monoplane with downward-sweeping wing tips. Also in 1910, Hugo Junkers of Germany patented an all-wing airplane, but the design was crude and the airplane was never built. In 1928, G.T.R. Hill, an English professor, designed the Pterodactyl Mk.IA, which incorporated pivoted wing tips that served as both ailerons and elevators. None of these airplanes was ever produced or flown successfully (Coleman & Wenkam, 1988).

In the United States, John K. Northrop had more to do with the development of the flying wing than anyone else. Early in his career, Northrop said "If something is efficient and beautiful, it is right" (Ford, 1997, p. 73). From 1919 to 1927, Northrop worked for the Douglas

and Lockheed (then spelled Loughhead) companies. In his spare time, Northrop and fellow employee Anthony Stadlam built an all-wing glider. Stadlam was a Czech-born barnstormer who had seen similar tailless aircraft in Europe. The Lockheed Company, however, was concerned with designing more conventional aircraft and discouraged Northrop from working on his flying wing. Northrop reluctantly complied and began work on the Vega aircraft. This aircraft was a great technological advance in that it had no external wing supports, a definite departure from the design of airplanes in that day. The Vega established 34 new world records for speed and endurance (Coleman & Wenkam, 1988).

Northrop left Lockheed to join Avion, a new aircraft manufacturing company formed in 1928, because he was discouraged by Lockheed's lack of interest in his flying wing. While working at Avion, Northrop was credited with creating an all-metal-skinned airplane called the Northrop Alpha, which was as successful as the Vega.

Avion allowed Northrop to continue his pursuit of the flying wing. Northrop's first attempt at a powered flying-wing aircraft occurred in 1929 -- the aircraft was called the Experimental No. 1. It was not a true flying wing because it still had a scaled-down tail with a rudder and elevator attached for balance. Northrop felt that this feature was necessary to flight-test his wing to determine

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if a pure all-wing airplane could be adequately controlled and flown. The aircraft had an all-metal skin with a wingspan of approximately 30 feet and was powered by a 90-horsepower Menasco four-cylinder engine. The airplane proved to be very stable and it outperformed aircraft of similar horsepower. Even though the aircraft was not a true flying wing, it represented a monumental step toward the development of an all-wing aircraft (Coleman & Wenkam, 1988).

Meanwhile, the Europeans also were trying to perfect a flying-wing airplane. Due to the Treaty of Versailles, the Germans were restricted from developing powered aircraft. The Horten brothers of Germany achieved fame as designers of elegant flying-wing sailplanes, the most famous of the time (1937-1938) being the Horten "Soaring Wing." It was an advanced prewar all-wing sailplane. Had the Germans had the freedom to develop powered aircraft earlier, they might have surpassed Northrop's attempts in the United States (Rolfe, 1952).

World War II was starting in Europe, and again the emphasis for development of airplanes was switching to wartime use. In 1939, Northrop formed the Northrop Corporation to undertake the design and manufacture of military aircraft. It was perfect timing for the Northrop Corporation -- not only did it receive orders from Norway and Britain, but also from Boeing and Consolidated. The company grew rapidly. During World War II, the company built 1,131 aircraft of its own design and was engaged in extensive subcontract work. Due to Northrop's continuing dream of building the perfect airplane, he also devoted considerable attention to the design and construction of aircraft of the flying-wing type (Taylor, 1973).

For help in this area, Northrop recruited Dr. Theodore Von Karman. Von Karman was one of the world's leading authorities on aerodynamics and taught at the California Institute of Technology. William Sears, one of Von Karman's brightest students, also was brought in on the project. Analyzing Northrop's hand-drawn sketches, both Von Karman and Sears agreed that Northrop's flying-wing concept was practical and a necessary evolutionary breakthrough in aircraft design. Northrop's aerodynamic engineers started to mathematically check out his design. Northrop's concepts were not based on

anything previously designed because no aeronautical literature existed on how to design a flying wing or how to calculate its performance. His airplane was a totally new airplane. In 1939, computation of dynamic stability was beyond the ability of aeronautical engineers. If useful equations had been available, the calculations would have been impossible to do in a practical amount of time using the mechanical calculators and slide rules of the day. Von Karman's expertise proved invaluable. What would have taken Northrop's engineers three days to calculate, Von Karman could complete in less than an hour using new equations and a blackboard (Coleman & Wenkam, 1988).

Northrop first constructed a small-scale model from balsa wood with about a 15-inch wingspan and then they took the model to the Pasadena Civic Auditorium to fly. One of the major concerns was that if the airplane entered a spin it would be unrecoverable due to the lack of a tail. After several launches and attempts to put the glider in a spin, they were surprised to find that the model always returned to stable flight and glided to a smooth upright landing. Another glider model that had a larger 30-inch wingspan was built out of pine and was tested in a wind tunnel. The engineers were convinced, even without the calculations to prove it, that Northrop's airplane would be safe to fly (Coleman & Wenkam, 1988).

In 1940, the plans were complete and the first true tailless flying wing was constructed -- the experimental prototype (Bullard, 1997). It was built using the conventional wooden construction of the time. The pilot sat inside the wing. It had a 38-foot wingspan with wing tips that could be adjusted to droop down. The wing sweep also could be varied by the use of v-shape inserts where the outer wing panels joined the mid-wing/fuselage. All of these adjustable surfaces would prove valuable in the upcoming flight tests. The N-1M had all of its control surfaces, including the rudders, in the trailing edge of the wing. Ailerons and elevators were combined into one unit, called elevons. These devices operated in synchrony for pitch control and differentially for roll control. Rudder control for yaw was provided by wing tip-mounted split-clamshell flaps that opened to create drag on the desired side. The N-1M was powered by two 65-horsepower Lycoming O-145 four-cylinder air-

cooled engines connected to propellers by long shafts that were directly out the rear of the airplane (pusher). During the first flight test at Muroc lake bed the N-1M proved to be extremely underpowered. It could not fly out of ground effect and basically rode its own cushion of air created by the wing about 20 feet above the ground. Northrop said "It looks like we have an airplane with a 20-foot ceiling" (Ford, 1997, p. 75). The Lycoming engines were replaced with six-cylinder Franklins that provided 117 horsepower each. This allowed the N-1M to break out of ground effect (Bullard, 1997).

Through additional testing, it was discovered that the negative dihedral caused by adjusting the wings to droop proved to be too unstable. The aircraft was already inherently unstable due to the lack of a tail. Also, it was discovered that the farther the wings were swept back the more stable the aircraft became. The wing tips placed farther aft of the center of gravity tended to act like a tail for a stabilizing effect. So the best overall configuration was with no wing droop and the wings swept back as far as possible. Also, the new Franklin engines tended to overheat.

The war was firing up in Europe and the U.S. Army was extremely interested in new technology. With the generally successful demonstration of the N-1M, the Army encouraged further development of the flying wing. Because the flying-wing aircraft used the whole airplane to provide lifting force, it would allow the Army to carry a heavier load of people, cargo, or bombs than other airplanes of the same size (Berliner, 1986).

As time went on, Americans became more concerned that the United States would become involved in the war. Germany's war machine was in high gear, continually developing new aircraft prototypes. They developed 17 prototypes in 1939 and, at the high mark, 27 in 1944, with the thought of possibly having to bomb the United States. By 1941, German troops were marching over most of Europe and into Russia. Seeing the possibility of a transatlantic war, the U.S. Army wanted a superbomber that could carry enough fuel and bombs for a nonstop flight to Germany and back (Baumbach, 1960).

Northrop took on the challenge and designed the XB-35. The Army was so intrigued that it agreed to fund the development of two XB-35 aircraft with a possible

followup contract for 200 more. The "X" was the Army's designation for experimental and the "B" stood for bomber. Once the airplane went into service test for the Army, the "X" would change to a "Y," which stood for service test. The airplane was such a huge step forward technologically that the Army also agreed to fund a scaled-down version of one-third the size. This aircraft became known as the Northrop N-9M and was built as a test bed for its upcoming big brother, the XB-35. Four of these aircraft were built, with the first one delivered behind schedule and overbudget. The airplanes were powered by two 260-horsepower Menasco C6S-4 engines and two 300-horsepower Franklins. It had a total fuel capacity of 100 gallons.

The first test flight took place in December 1942. Production of the XB-35 was gearing up and the pressure was on Northrop for the N-9M to perform. He was concerned about the airplane's lack of lateral stability. This concern turned out to be genuine: The airplane tended to rotate irregularly about the lateral axis. Another problem with the airplane was its stall characteristics. With a swept-wing design, the airplane tended to stall at the wing tips. Not only had the aileron authority been lost, but it had also lost its elevator authority because the controls were combined into elevons. The stalls were unpredictable and dangerous. The N-9M could suddenly pitch up or just slide off to one side and enter a spin. The airplane claimed its first casualty due to a stall in May 1943 (Coleman & Wenkam, 1988).

At this time, Northrop was working on another project as well. He was trying to develop the first jet fighter, an aircraft called the XP-79 that also used the flying-wing concept. It was another unusual airplane, in that the pilot lay in the prone position to help counter the effect of g-forces while performing high-g maneuvers, especially when pulling out of a dive. Three aircraft were built and two were powered by two 2,000-pound-thrust Aerojet rockets. The first aircraft was never flown. The third aircraft was powered by two 1,345-pound-thrust Westinghouse 19B axial-flow turbojets. The aircraft had two small tail fins added for stabilization. The second aircraft, called the XP-79A, was redesigned as a rocket-assisted glider and was redesignated the MX-324. It was

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towed into the air by a Lockheed P-38 Lightning fighter and on July 5, 1944, it became the first American rocket-powered airplane to fly. The aircraft had a wingspan of 38 feet and a length of 14 feet. It was constructed of heavy welded magnesium wings to be used for ramming if its four 0.5 mm machine guns had not done the job. For the increased strength, the aircraft was heavy for its size, weighing 5,840 pounds. The XB-79 series had a designed top speed of 526 mph and a range of up to 990 miles. Unfortunately, its first and last flight was on September 12, 1945, after being launched by air tow. The airplane crashed, killing its pilot and ending the program. It was the only airplane in U.S. history designed specifically for ramming (Pollinger, 1967).

In 1945, the tide of war had turned against Germany but flying transatlantic was still on Hitler's mind. The Horten brothers were permitted to continue with the development of their version of the flying wing, considered the most daring of all German jet-bomber designs. The airplane was called the Horten Ho IX V-2. Like most devotees of drag-reduction and efficiency, the Hortens thought in terms of speed and fighters. Their approach to what was called their ninth design was considered a jet-propelled fighter. The Germans called it a fighter-bomber and on that basis redesignated it as the Gotha 229. Two prototype lines were developed, one as an all-weather fighter and the second as a trainer and fighter-bomber. In January 1945 it became the world's first turbojet-powered flying wing (Coleman & Wenkam, 1988). The first tests were successful at lower speeds and the tests gradually were increased. By the spring of 1945, it was ready for high-speed tests and achieved one run at close to 500 mph. However, a problem arose on the approach to the airfield -- one engine flamed out and the aircraft went into a bank and slammed into the ground in a ball of fire. The test program was halted and the Gotha prototypes were not completed in time to fly in the war. One of the Gotha prototypes had almost been finished but was bombed by the Allies in the factory. If the war had lasted longer, the Gotha 229 could have proven a lethal weapon against the Allies.

Meanwhile, Alexander Lippisch at Messerschmitt designed the Me163, the first operational flying-wing fighter. Still on the drawing board when Germany

surrendered was project P12, an experimental ramjet fighter that bore a remarkable resemblance to Lockheed's 1987 ATF stealth fighter (Coleman & Wenkam, 1988). The Germans might have had a much greater impact on the development of future all-wing aircraft design had the war lasted longer or had the war's outcome been different. With Hitler's defeat, the German attempt at a flying wing was over (Anderton, 1979).

Unhappy with Northrop's progress, the Army canceled its contract for the XB-35 except for two experimental planes and two service test beds. Northrop continued working on his four prototypes of the XB-35. On June 25, 1946, the first aircraft took to the air. It had a wingspan of 172 feet and a length of 53 feet. Each elevon had an area of 182.3 square feet. The airplane had an empty weight of 95,339 pounds and had a max gross weight of 225,344 pounds, a massive airplane for its time. Even at max gross weight the wing loading was only 38.8 pounds per square foot, a definite advantage of the flying wing. The normal crew consisted of nine, with six crewmembers for relief. The aircraft was powered with four Pratt & Whitney R4360-1721 Wasp Major engines equipped with General Electric turbo-superchargers. Each engine had 28 cylinders with Hamilton Standard eight-blade coaxial pusher props. For armament, the XB-35 had twenty .50-caliber machine guns and could carry thirty-two 1,600-pound bombs at a range of 10,000 miles and at a top speed of 391 mph (Bullard, 1997).

Company pilot Max Stanley flew the XB-35 to Muroc Army Air Base without difficulty. Thereafter, the XB-35 was plagued with problems. Its engines typically overheated because of the 30-foot-long drive shaft from the propeller to the engine, and vibration was a continuing problem. The engine-driven gearbox also was troublesome. The XB-35 models logged a total of 36 hours with an amortized cost of \$1.8 million per hour (Bullard, 1997).

Despite the problems, neither Northrop nor the Army was discouraged. Before the war's end, much of the flying-wing program had been classified. Now, with possible applications in the commercial market, Northrop finally was able to publicize his progress. With the advent of the jet engine, the Army wanted Northrop to replace the old piston engines with new jet engines. Northrop

had never wanted to use the engines, gearboxes, and propellers that were installed in the XB-35, but due to government contracts he was forced to use what he considered substandard parts. The jet engines would have to be an improvement over the vibration caused by the long drive shafts and props. Eight General Electric Y-35-A-5 jet engines replaced the piston engines and propellers. As far as Northrop was concerned, the flying wing would now be unbeatable (Coleman & Wenkam, 1988).

Initial flight testing of the YB-49 took place in 1949 and proved successful. Four small trailing-edge fins were added to compensate for the loss of directional stability caused by removing the reciprocating engines and propellers. The plane had a cruising capability of 400 mph at 40,000 feet and a range of nearly 4,000 miles. It was unprecedented in its day and for many years held the longest range of any jet-powered airplane in the world. General Roger Ramey, 8th Air Force commander, said "The YB-49 is the fastest bomber I have ever flown -- a fine ship with a real future" (Coleman & Wenkam, 1988, p. 123). The YB-49 set many range and speed records from 1948 to 1949.

Northrop continued to search for funding to produce more of his aircraft. He converted other XB-35 aircraft that had not been bought by the military to the more advanced YB-49. Another unplanned advantage of the YB-49 was discovered. When the aircraft flew toward the San Francisco coast, radar was unable to pick up the airplane until it was almost directly overhead. The Air Force, at that time, did not realize that this unique stealth characteristic is a desirable attribute for a strategic bomber.

The military's concern was that the plane tended to yaw and zigzag during bomb runs. They did not think it could deliver a bomb accurately. Northrop incorporated a Honeywell autopilot that eliminated the yawing problem and made the airplane much easier to fly. The Air Force was pleased with the progress and announced that the YB-49 was the longest-range jet aircraft in the world. Four months later the second airplane was delivered, but things were about to change.

Since its original delivery nearly five months earlier, the YB-49 had accumulated 66 flying hours incident-free.

Now, the test stage was being turned over completely to military pilots who had never flown an all-wing aircraft. Northrop test pilots offered their experience and flying skills but were ignored by the military. On June 5, 1948, the YB-49 flying wing crashed in the Mojave Desert, killing everyone aboard. Nothing could be absolutely proven, but it was theorized that the maximum speed of the aircraft was exceeded. Witnesses saw the plane falling in pieces. Because the plane had no ejection seats, no one could escape. Also, sabotage was not ruled out.

Ironically, a few days later Northrop was summoned to meet with General McNarney in Washington, D.C. The Air Force had agreed to a contract to buy 30 YB-49 aircraft from Northrop to be used for reconnaissance missions. The glory was short-lived; old competitors had more political power than Northrop did. Northrop was summoned to meet with Secretary of the Air Force Stuart Symington, who said: "I want Northrop combined with Consolidated" (Coleman & Wenkam, 1988, p. 141). The Air Force wanted production of the YB-49 turned over to Consolidated. Northrop was dismayed and could not believe the Air Force could be so politically corrupted. For a government official to demand corporate mergers that would affect competitive bidding was ludicrous. Major Cardenas, a military test pilot, also found out later that his test reports had been altered. It was never discovered who had revised the reports.

Northrop's flying wing, which he had spent years developing, was obviously superior to any other aircraft of the time. Northrop was not going to sell out the company that he had worked so hard to build and certainly was not going to turn over the production of his aircraft to another company. Northrop refused the request (Coleman & Wenkam, 1988).

The Air Force canceled the contract to build the YB-49 and ordered the scrapping of all unfinished airplanes. The airframes, having been funded by the government, were government property. Eleven aircraft were cut into pieces and hauled away in dump trucks. All test reports were destroyed and as far as the Air Force was concerned the YB-49 no longer existed. The Smithsonian Institute's request to exhibit the aircraft was denied.

Northrop's dream of the flying wing was destroyed. A few years later, Northrop resigned from his company,

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although he later rejoined it in an honoree salaried position. Northrop died in 1981, but before his death one of his old colleagues showed him a picture of an airplane being designed by the Northrop Corporation. The airplane was the conceptual drawing of the B-2 bomber (Coleman & Wenkam, 1988).

Northrop's dream was not dead. Due to the military's increasing need to penetrate areas heavily defended by radar, the flying wing was reborn. The *Wall Street Journal* reported in early 1988 that Northrop Corporation had received a \$2 billion contract to build the B-2. Competition and the plane's high cost again threatened the life of the B-2, but luckily for the Northrop Corporation the program was highly classified and not easily derailed. The Air Force contracted with Northrop for the procurement of 132 operational B-2 aircraft. With the demise of the Soviet Union, the number was reduced to 20 operational aircraft plus one test aircraft (USAF, 1997).

The first B-2 aircraft was publicly displayed on Nov. 22, 1988, as it rolled out of the hangar at the Air Force Plant, Palmdale, California. The B-2 is a multi-role bomber capable of delivering both conventional and nuclear munitions. The bomber represents a major milestone in the U.S. bomber-modernization program. It has a worldwide reach with its refueling capabilities. It is powered by four General Electric F-118-GE-100 engines with 17,300 pounds of thrust per engine. The B-2 has a wingspan of 172 feet and a length of 69 feet. It is a high

-subsonic-speed aircraft with a ceiling of approximately 50,000 feet. Its unrefuelable range is approximately 6,000 nautical miles, with a 40,000-pound payload. The B-2's stealth characteristics give it the unique ability to penetrate an enemy's most-sophisticated defenses and threaten its most-valued assets. Many aspects of the aircraft's low observability remain classified; however, the B-2's composite materials, special coatings, and flying-wing design all contribute to its stealthiness. On-board sophisticated computers make the B-2 a pilot-friendly airplane to fly. All B-2s are stationed at Whiteman Air Force Base, Missouri. The Spirit of Missouri was the first aircraft to be delivered, on Dec. 17, 1993, and B-2s continue to be delivered as they are produced. The airplane is planned to be an effective deterrent well into the 21st century (USAF, 1997).

New uses for the flying wing are under continual development. Flying enthusiasts are designing and building small-scale versions of the flying wing. Boeing Commercial Airplane Company has been studying possible applications for civilian and military transports. NASA has prepared design criteria for a flying-wing cargo plane. Cargo- and passenger-hauling airplanes of the future could come from the all-wing design due to its high-lifting capability and efficiency.

The true flying-wing concept was almost a century in the making and has made its place in history for now. One can only envision the future possibilities.□

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