Reflections

by George C. Larson

The "Flying Wing"

Airplanes have traditionally been designed so that their stability was usually inherent in the configuration. The degree of stability in each airplane may have varied, but the airworthiness of a design always hinged on meeting the rules that define basic aerodynamic stability. Artificial stability has replaced the stability conferred by configuration, at least in advanced military aircraft, but that's a fairly recent development.

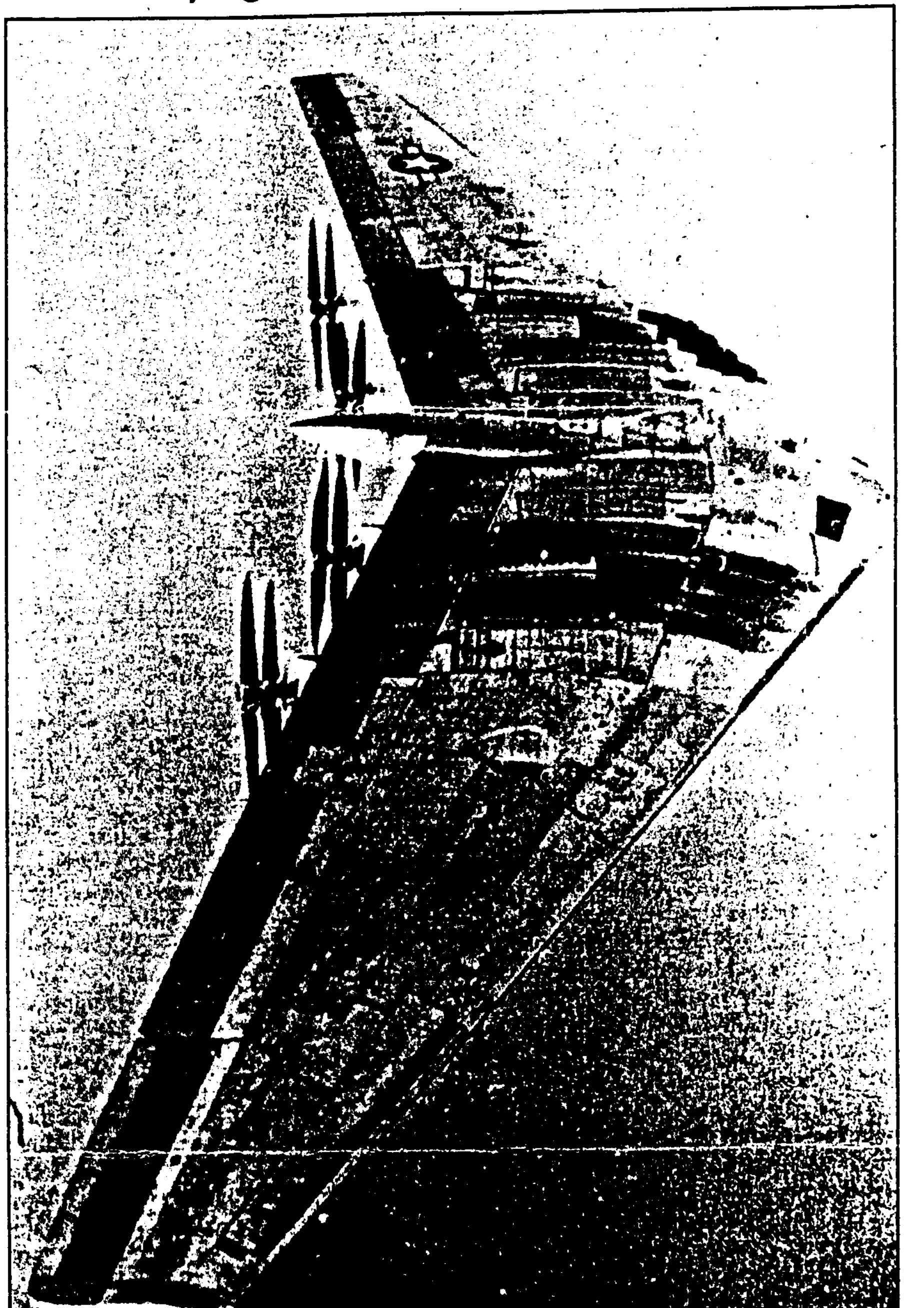
In most conventional airplanes, stability in pitch is conferred by balancing the forces of lift and the airplane's weight. In all contemporary business airplanes, this is accomplished by using a second (or even, in one case—the Gates-Piaggio GP-180—a third surface to provide a balancing force. An elevator or canard provides that balance, offsetting the lever arm that exists between the airplane's c.g. and its center of lift. The length of that arm is normally very short, perhaps only a few inches; but the forces are comparatively large. The product of the two—the force times the distance in that lever arm—is the moment. The greater the moment that exists around the c.g. due to the wing's lift, the greater must be the matching moment from the balancing surface.

But suppose the center of lift and c.g. could be managed so that a balancing surface becomes unnecessary? If that were the case, the traditional airplane would not require a separate tail. And when a designer can get rid of the tail, some immediate benefits are realized.

For one thing, more of the airplane's structure can be put to work creating lift. Although that lift creates its normal share of induced drag, the so-called "wetted area"—the amount of surface skin over which air must pass—is reduced dramatically. The heavy structure of the fuselage can be eliminated, since it is no longer required to bear the loads associated with the tail, thereby saving weight.

The airplane also benefits structurally in that it can be designed so that all loads are carried within the wing—since there's no fuselage anymore—and spread across a wide section of span. "Span loaders" are ideal for carrying a lot of weight with a minimum of structure to support it.

Tailless airplanes exist in numbers great enough that they can't be considered unusual. Any delta-wing airplane manages to fly without a separate balancing surface. (In many cases, they maintain their designed c.g. range by transferring fuel among various internal tanks.)



In final form, the Flying Wing's control surfaces were arranged with trim surfaces and drag rudders combined at the wingtip; next, were elevons and finally, the flaps.

But one tailless design—the Northrop Flying Wing—remains one of the most controversial airplanes ever built in the United States. Perhaps no single airplane before or since has been so wrapped in myth and misunderstanding. The controversy itself has engendered a belief that the design was somehow flawed, which is both unjust and untrue.

Jack Northrop may have been the only American engineer of his time with the intellect and persistence to develop and promote the flying wing concept. His career began at Lockheed with the design of the incomparable Vega monoplane, the performance of which stood aviation on its ear. That the Vega's form followed function was a Northrop signature, and it must be said at the outset that throughout his pursuit of the aerodynamic ideal, Northrop was notable for his mental ability to begin anew from the first premise, to think as if he were constantly confronted by a clean sheet of paper.

He left Lockheed in 1928 to form the Avion Corporation, and there he built a 1929 design that flew successfully with the balancing tail surface minimized to the point of being vestigial.

This airplane was named the Flying Wing, though it was not, strictly speaking, a tailless airplane, and to historians, it is more often cited for its advances in construction, including stressed all-metal skin around a "multicellular" structure.

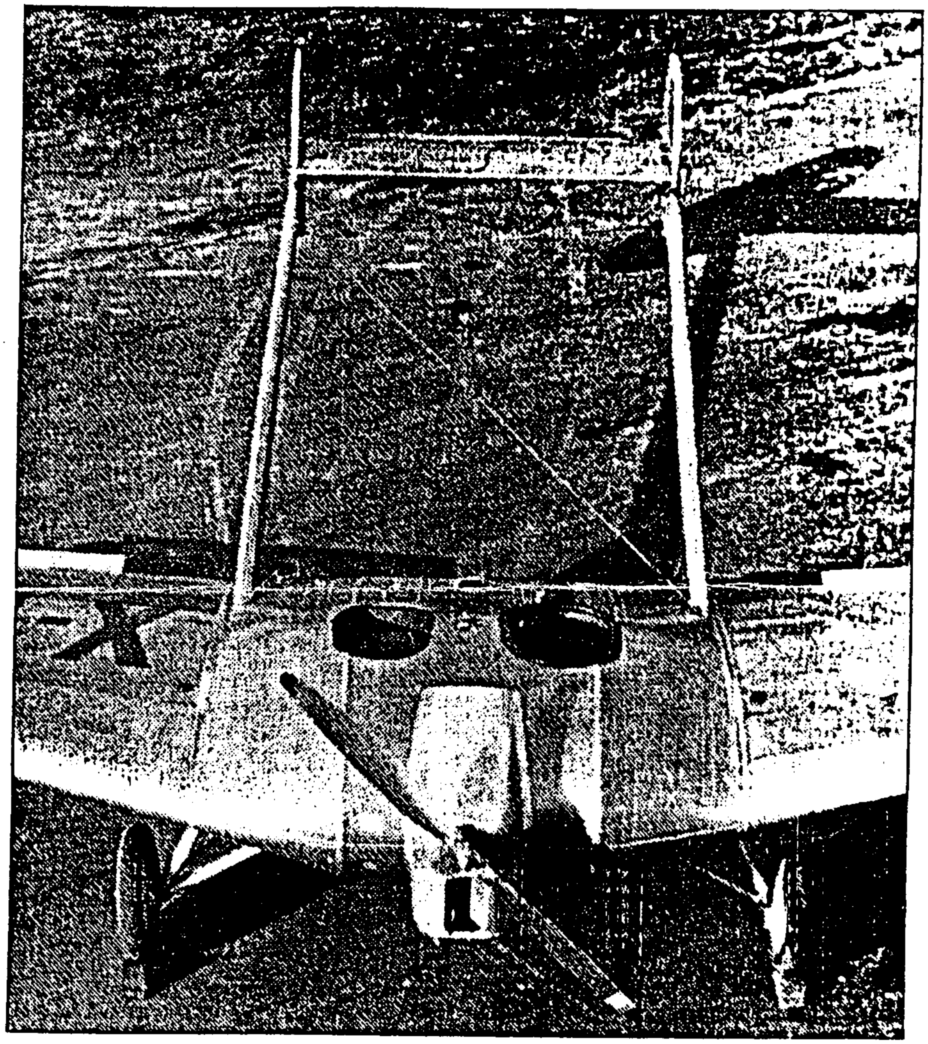
Avion folded, to be followed in 1932 by El Segundo, California's Northrop Corporation, which later became a division of Douglas. In 1937, Northrop and Edward Heinemann tested a tailless design in the wind tunnel and found it wanting.

By 1939, Northrop was on his own again (Heinemann remained at Douglas), forming Northrop Aircraft, the founding company that bears his name today. Where most owners of aircraft manufacturing firms would probably have been thrilled to land a production contract, all evidence appears to indicate that as far as Jack Northrop was concerned, money from sales was merely a means to advance his real love: research.

The configuration Northrop sought was based upon a great deal of work that had gone on before he tackled the idea. Even as far back as Alphonse Penaud's 1871 demonstration of a rubber-powered model, the outline and even some of the features of a flying wing could be identified. In the 1890s Clement Ader followed with his *Eole*, a true tailless airplane that incorporated variable geometry in the wing so that the geometric center of lift could be altered. Ader has been credited with some flights, but the conditions under which they were made negated much of his claim to have been first to fly a heavier-than-air machine.

Jacob Ellehammer, a Dane, did build and successfully fly a tailless airplane powered by an engine of his own design in September 1906, and after him, a number of Europeans refined the concept, some of them more successfully than others. They borrowed their shapes from the inspiration provided by nature's flying seed pods and animals (some of them extinct, which should have proven a warning but didn't); such was Igo Etrich's remarkable boomerang-like 1909 flying machine, which demonstrated a high degree of stability—a seeming contradiction for a tailless airplane.

But Englishman John Dunne designed tailless airplanes for exactly that reason: the desire to enhance stability. His wings were made to "wash out," that is, to produce a gradually diminishing angle of incidence from root to tip until, at the wingtips, the wing was actually exerting a downforce—thereby balancing the whole. The wings were also swept to create a moment arm, however minimal, and directional stability. The Dunne configuration established those ideas and demonstrated their practicality as far back as 1910.



One of the first attempts at designing a so-called "Flying Wing" was not actually a tailless aircraft, but was of interest for its structural advances.

The Germans embraced the tailless configuration with a vengeance. Hugo Junkers adopted it, and it was perfected by Alexander Lippisch, whose tailless, swept-wing fighters were arguably the most advanced designs of any nation (or even of any individual, for that matter) to see service in World War II.

Americans, too, were active in tailless design. The first to touch on the concept was Vincent Burnelli, who really aimed at the span-loader idea with a "lifting body" fuselage shaped like an airfoil intended to contribute to lift. (Anyone who has seen an experimental design called the Hyperbipe perform its aerobatics routine at air shows can imagine Burnelli's design without seeing it in a photograph.) And then there was Northrop.

Northrop's ultimate goal seems to have been an aircraft that, in level flight, comprised only a wing, with no other surface at work in the airstream. All loads—engines, passengers, freight and fuel—would be distributed internally inside the wing itself. "Elevons" combined the control of elevators and ailerons in a single set of trailing-edge surfaces. At the wingtips, a drag-creating device was used to provide yaw control. On the N-1M, the first of Northrop's flying prototypes, yaw control was provided by a pair of trailing edge surfaces that split apart to create the required turning moment, and though Northrop experimented with other devices, the split flap was most prevalent.

The N-1M was also almost completely "adjustable." Wing sweep, wingtip droop, and dihedral could be ground-adjusted to measure their effect upon flight characteristics. Using this flying scale-model-cum-mannequin, Northrop and his group of engineers arrived at the best compromise of wing geometry to yield the desired handling characteristics.

The N-1M was discarded after it had served its purpose, and Northrop began developing the N-9M, a much more detailed expression of the final form the flying wing would take. The outline and arrangement were almost fixed, especially the arrangement of control surfaces.

Outermost on the moderately swept wing were hinged surfaces resembling ailerons but actually comprising pitch-trim surfaces. On a swept wing, the tips are aftmost; therefore, the tips are the logical location for pitch-trim control. In that respect, one can regard the flying wing as an airplane in which both wingtips function as a pair of horizontal stabilizers. Within these trim surfaces were a second set of surfaces comprising the "rudders," which functioned as in earlier prototypes by contributing drag to the wingtip inside the turn, thereby controlling yaw.

Progressing toward the root, the next pair of surfaces comprised elevons—elevators and ailerons combined. Finally, at the center, were located the landing flaps. The airplane lacked any form of vertical stabilizer, which may be what led to the notion in some minds that a flying wing in that form lacks directional stability. In fact, the wing's sweep contributes adequate directional stability through lift and induced drag, though some unwanted roll is introduced in the process.

A number of N-9Ms were built for testing, intended to represent one-third scale models of the eventual long-range bomber that Northrop and his Air Corps sponsors intended. The first was built with unusual rudders that resembled split wingtips, the two halves of which opened upward and downward to form a vertical surface. The first N-9M was lost in a spin accident, killing the pilot and leading to some suspicions about the stability of the configuration, so wind tunnel testing was resumed. Later, fixed slots were added on the outer portion of the wing to delay tip stalls, and recoveries from half-turn spins were made successfully. Both Northrop and the Air Corps began to breathe a bit more easily.

The program resulted in a contract for Northrop, first for the recip-powered XB-35, then the jet-powered YB-49, but factions within the Air Corps maintained a persistent complaint about the airplanes' suitability. The Flying Wing bomber had a successful first flight on June 25, 1946, and by that time, the jet engine was already replacing recips. The relatively thick airfoil on the Northrop design was not particularly well adapted to high Mach numbers, and arguments never seemed to let up about the stability of the airplane on a bomb run. In the end, the project was scrapped, probably for reasons so complex and intertwined that a single cause could never be named.

In an interview given shortly before he died in 1981, Jack Northrop blamed politics in Washington for the demise of these airplanes—in their time, the most startling sight anyone had ever seen in the air. Fans of late-night B movies may catch a glimpse of the Flying Wing in the film of H.G. Wells's *War of the Worlds*, but none of the huge bombers was saved for preservation.

In a way, it was unfortunate that Northrop had to aim his design at a strategic bomber, but only the military could afford the years of research it took to create the Flying Wings. Those aircraft were much better suited to the task of an air freighter: carrying heavy loads over long distances.

The Flying Wing was not flawed, nor was it really radical, though admittedly, it looked unusual. The airplanes are, at least, an important reminder to every aircraft designer that the form that an airplane can take derives first from human imagination. Kind of makes you reach for that clean sheet of paper. □

Readers wishing to learn more about the Flying Wing may seek the source for this article: Winged Wonders, *by E. T. Wooldridge, which is available through the National Air & Space Museum, Smithsonian Institution, Washington, D.C.*