

Skeleton Alleged in the Stealth Bomber's Closet

A 40-year-old dispute over the range of "flying wing" aircraft has been resurrected in a critique of the B-2

A MATHEMATICAL ERROR in an appendix to a secret report completed 43 years ago has come back to haunt its authors—and, perhaps, the Air Force's controversial B-2 "Stealth" bomber program.

Joseph V. Foa, an emeritus professor of engineering at George Washington University, has charged in a memorandum he circulated recently among scientific organizations and members of Congress that there has been "an unrelenting effort to conceal the facts and to obfuscate the record" about what he claims is the inferior range of jet-powered "flying wing" aircraft such as the B-2.

Foa, whose 40-year research career included a decade as chairman of the department of aeronautical engineering and astronautics at Rensselaer Polytechnic Institute, traces what he labels a "cover-up" of the flying wing's alleged deficiency to an embarrassing error in research performed for the Air Force in 1945 by two Northrop Corporation aerodynamicists. Northrop at the time was the prime contractor for an all-wing bomber that is generally viewed as a precursor of the B-2, which is also being built by Northrop.

The paper by William R. Sears and Irving L. Ashkenas was part of a secret assessment of promising military technologies undertaken in the immediate aftermath of World War II. A team of prominent scientists and engineers directed by Theodore Von Karman surveyed such fields as aviation, rocketry, electronics, and psychology to identify the most fertile areas for future development. Sears, a former student of the illustrious Von Karman, was Northrop's chief of aerodynamics and Ashkenas was his assistant. Von Karman and Sears are widely credited as the guiding lights behind the Northrop XB-35 and YB-49 flying-wing bombers of the 1940s, which were scrapped by the Air Force after the production of 15 airframes.

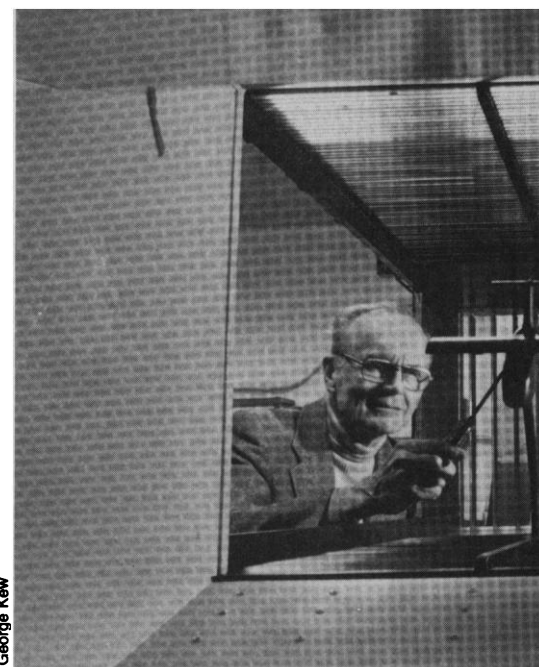
In their paper, which was delivered to General Henry H. "Hap" Arnold at the beginning of 1946 and then circulated among top Air Force officials, Sears and Ashkenas made frequent reference to the promise of all-wing aircraft. Only two tech-

nical appendices were attached to the general discussion, one that analyzed some of the still-novel flight characteristics of rockets and another that claimed to prove mathematically that, for best range, an airplane's volume should be contained almost entirely in the wing. At the time, Northrop was in a fierce competition for a contract to build a strategic bomber for the Air Force. It was developing the exotic XB-35—a visually stunning tailless span of 172 feet, powered by four 3000-horsepower propeller engines.

The XB-35's test program turned out to be plagued by mechanical problems with the prop engine assemblies, as well as questions about stability. In the early months of 1947, while Northrop was converting the XB-35 to a turbojet version tagged YB-49, Foa headed a research group at the Cornell Aeronautical Laboratory in Buffalo, New York, that was studying the range and aerodynamics of an unmanned jet-propelled aircraft called Hermes. Sears had recently left Northrop to become chairman of Cornell's graduate school of aeronautical engineering in Ithaca. During his theoretical work, Foa came upon what he thought was a remarkable contradiction of conventional wisdom, namely that—based on aerodynamic considerations alone—the range of Hermes would be considerably lower with an all-wing configuration than with a traditional wing-fuselage shape. As he looked into the problem further, he convinced himself that the result was universally true for jet-propelled aircraft: an all-wing shape would always have range inferior to a wing-fuselage shape, with other specifications being equal.

In April 1947, Foa brought this finding to the attention of Sears and suggested in a letter to the Laboratory's hierarchy that they submit a proposal to the Air Force for more research into its implications—"especially in view of the large sums of money that are now being spent to maintain leadership in a race which is apparently running on the wrong track [i.e., the Northrop YB-49 project]," he wrote.

Foa does not recall encountering a well-spring of enthusiasm. "Sears responded by stating, in effect, that what I was claiming was absurd, that he and Irving Ashkenas had



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rigorously proven in a Northrop report (of which he could not provide me a copy) that the optimum configuration for range in the case of the YB-49 was indeed a flying wing, and that we should definitely not proceed with the submission of the proposal I had suggested," Foa writes in his current memorandum. "It was not until 3 months later that I was able to see the Sears-Ashkenas report," which turned out to be the appendix to the secret 1945 Air Force study.

In that mathematical exercise, Sears and Ashkenas had written formulas involving such standard parameters as weight, flying speed, thrust, fuel consumption, drag, lift, and air density that could be manipulated to reveal how an aircraft's volume should be proportioned between wing and fuselage for best range. The formulas were valid, Foa found, but when Sears and Ashkenas calculated the maximum and minimum values for the ratio of total volume to wing volume, they reversed the correct answers.

In the jargon of calculus, the vanishing of the first derivative of range with respect to volume had given two solutions, one where the total volume was almost all in the wing and another where the wing volume was much less than the total. Sears and Ashkenas then simply stated that "it can be ascertained that the former gives a maximum range, while the latter gives a minimum." But with his own contrary research in the back of his mind, Foa examined the calculations and found that the Sears-Ashkenas "maximum" was in fact a minimum. "In other words, the flying wing was the aerodynamically worst possible choice of configuration for the YB-49," Foa writes in his recent memo.

On 15 July 1947, Foa sent a letter to



Joseph Foa. "The flying wing was the aerodynamically worst possible choice of configuration for the YB-49."

Sears pointing out the error. Sears replied on 17 July, saying "As you can imagine the error is embarrassing to Irv and me—although I hardly suppose anyone has taken serious action as a result." It certainly appeared that the optimum configuration was not a flying wing, Sears admitted. Nonetheless, he ended his letter by stating his opinion that the Laboratory should not undertake further study of the problem for the Air Force. "I suspect you will find that they have enough studies from airplane manufacturers so that they wouldn't be particularly excited about the proposal," Sears wrote.

"I found his response shocking," Foa recalls, but he says he felt "that the only responsible and honorable way out of it was for Sears himself to disclose the truth." Foa says he asked the Laboratory's director to tell Sears that if he or Ashkenas would do so, "I would not find it necessary to make any public statement on the matter of my own, and would agree to remain silent." Meanwhile, the YB-49 began test flights in October 1947.

The reaction to Foa's ultimatum was a paper written by Ashkenas titled "Range

performance of turbojet airplanes" published in the February 1948 issue of the *Journal of the Aeronautical Sciences*. In it, Ashkenas engaged in a far more abstruse parametric study than the one appended to the 1945 Air Force report. A crucial graph showed that for certain values of a dimensionless factor he called the "geometric shape parameter," the all-wing configuration gave best range. Foa's interpretation of the text indicated, however, that these values would produce a wing impractically thick.

Foa sent a critique of Ashkenas's paper to the *Journal* on 13 December 1948. It was published in the magazine's April 1949 edition along with a contentious reply from Ashkenas, with no further debate on the record.

A month after Foa's critique was sent in—on 11 January 1949, to be precise—the Air Force canceled Northrop's YB-49 contract. The official reason was budget limitations, but aviation historians still argue about the technical and political aspects of the decision. According to Northrop publications, the YB-49 achieved a range of 3155 miles with a 16,000-pound bomb load. In Von Karman's introduction to the secret 1945 Air Force study, he had stated the range goal as 3500 miles with 20,000 pounds of bombs. Later in 1949, the Air Force told the House Armed Services Committee that "the YB-49 showed considerable promise in speed and altitude but had inadequate range."

There the matter rested until it was revealed that the B-2 would be a flying wing like the YB-49.

Sears and Ashkenas, while acknowledging their old error, do not take Foa's underlying concerns seriously. Today, Sears is emeritus professor of aerospace and mechanical engineering at the University of Arizona, where he moved in 1974 after a distinguished career at Cornell that spanned nearly three decades. Reached by telephone in Tucson, he declined an opportunity to respond in detail to Foa's memorandum. "Of course we were embarrassed by it," he said of the 1945

error, but "we never agreed with Foa about his conclusions." Engineers "make these parameter studies to get general trends," he noted, and they are of limited value in the real world of aircraft construction. "It never seemed very important," he added. "It didn't change anything."

Irving Ashkenas, now vice president of Systems Technology Inc.—a consulting firm in Northrop Corp.'s hometown of Hawthorne, California—remembers the appendix to the 1945 Air Force report as "just a little simple exercise that I thought was cute, and that backfired on me." He says that no correction was ever issued (the report was not declassified until 1977). "It was a small part of my contribution and I don't recall worrying about it."

Both Sears and Ashkenas contend that other advantages to the all-wing design have been established in recent years that should more than make up for the aerodynamic penalty on range expounded by Foa. Chief among these is a theory called "span-loading," whereby the airplane's weight is distributed along the wing, resulting in relatively small bending moments and therefore a lighter structure. In a 1987 *Aerospace America* article, Sears went so far as to refer to the YB-49 project as "the world's first serious effort to prove or disprove the span-load theory for designing big airplanes."

If weight saving was hoped for in the B-2 design, then there are indications that Northrop has had difficulty obtaining it. In 1984, the B-2 underwent a major redesign costing at least \$1 billion that changed the aircraft's wing structure and decreased its weight. The Air Force's publicly stated reason for such massive rework was to give the B-2 a capability to fly low-altitude earth hugger missions, in addition to the high-altitude attacks initially posited for the bomber. But terrain-following flight, which requires continuous use of radar altimeters to maintain proper distance above ground, would negate some of the stealthiness that was the primary reason for selecting a flying-wing design in the first place.

Resolution of the Foa-Sears debate awaits the B-2 flight test program, which has yet to record its first hop, though the bomber was rolled out last November. Anyone outside the tight Air Force security circle can only speculate about related technical issues, but last week, House Armed Services Committee chairman Les Aspin (D-WI) noted that the aircraft is "new technology with perhaps fundamental problems."

■ WAYNE BIDDLE

Wayne Biddle is a Washington, D.C.-based journalist who is writing a book about the aerospace weapons industry.

Northrop's YB-49. A precursor of the B-2, it was canceled in 1949 ostensibly for budget reasons. Air Force officials later testified that its range was inadequate.

