LESSONS TO BE LEARNED FROM FULL SIZE TAILLESS AIRCRAFT

The show stopper of the scale slope meet in Richland in May of 1988 was a model of the Northrop YB-49. Many people take pride in recounting the experience of seeing the original YB-49 in flight, and anyone who has seen its graceful shape in the science fiction movies of the fifties can readily understand their awe. It was an absolutely beautiful airplane in the air, and the model at Richland was just as impressive. It was hard to imagine we were looking at a glider!

Nearly everyone now knows the B-2 "Stealth" is a flying wing, and based on the demise of the YB-49, there are of course questions as to the suitability of a flying wing as a bombing platform. To see the B-2 in proper perspective, it is wise to first get some facts about the YB-49. Along the way, perhaps we can learn something about the design and stability of our tailless models.

The YB-35 (propellor driven) and YB-49 (jet powered) flying wings proved the span-load theory for large aircraft. In a conventional airplane, the fuselage and tail assembly produce a large weight and inertia load on the wing-fuselage junction. Since there is no fuselage or tail assembly on the flying wing, the weight and inertia distribution is along the entire wing, and the bending moments are much smaller. Surprisingly, maximum loads on the flying wing may occur during landing rather than during in-flight maneuvering or gusts. If an airplane is to always land and takeoff at the same speed, then its weight can increase only with the square of its size. The bending moments, however, increase by size cubed, as does weight. You can thus build a bigger airplane, and obtain the effects of increased Reynolds Number and greater payload, by going to an all wing design.

Some of the quirks of full sized flying wings don't appear in RC models. The primary example of this is elevon loading at high angles of attack. A wing stalls from the trailing edge forward and so the pilot of a full sized flying wing would feel the elevators/elevons being lifted by the vacuum. If he did not keep forward pressure on the stick the rising elevators would contribute to an even higher angle of attack and a worsening stall condition. During such a stall, the pilot would view the airplane as being longitudinally unstable. It is felt the crash of the N9M (the one third size plywood forerunner of the YB-35) was due to just such a condition. The servos in our models don't perceive such feedback from the control surfaces, and we, as pilots, are infinitely removed from flight forces by virtue of the fact we are on the ground rather than in the cockpit. The YB-35/YB-49 had devices installed which prevented aerodynamic forces from being transmitted to the pilot.

The designers of the YB-35/YB-49 provided a means of achieving high lift for takeoff and landing. Although the airfoils used were symmetrical (NACA $65_1 3$-019 at the root, NACA $65_1 3$-018 at the tip), the wing twist was four degrees. This placed the root section at a positive angle during flight, with the wing tips exerting a small down force behind the CG. Flaps were used during takeoff and landing to provide the high lift needed, and they could be lowered 50 degrees. Since they were close to the CG their effect on the pitching moment was quite small.

Both the YB-35 and YB-49 were stable and controllable. The crash of the YB-49 piloted by Glen Edwards occurred during flight #25 of the testing program, while investigating low power stalls at high altitude. The airplane, whether due to excess weight, Edwards' piloting it outside the safe flight envelope, or another factor, flipped during a stall and somersaulted until crashing into the ground.

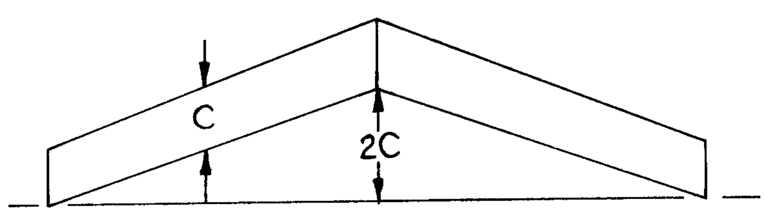
The demise of the YB-49 program probably was not due to the crash. Jack Northrop stated that while the YB-49 had won the competition with the B-36, the Air Force wanted the production lines to be at General Dynamics in Texas. There was a merger demand from the secretary of the Air Force, Northrop claimed the terms to be unreasonable, and the YB-49 contract was cancelled. Why the Air Force crews with torches destroyed all of the remaining YB-49s, even those on the assembly lines, is not known.

The B-2 "Stealth" takes advantage of many new technologies, including computer designed airfoil sections, composite construction techniques, and active flight controls. The resulting design is a high speed long range airplane. Add to all of this the fact an all metal flying wing without radar defenses produces one tenth the radar image of its conventional counterpart. Constructed of low reflectivity composites and endowed with a unique outline, the B-2's radar image will be very small, if it exists at all.

What, of all this, can we apply to our tailless models?

Any fuselage should be eliminated, if at all possible, to both reduce drag and take full advantage of span loading.

Problems which full sized flying wings have with shifting CG don't show up in our sailplanes. We have no fuel to use, no bombs to drop. If we're careful with CG placement, wing sweep and wing twist we needn't worry too much about instability. In an article in TWITT's Newsletter #4, Irv Culver (of Lockheed "Skunkworks" fame) promoted the idea outlined in the drawing below. Simply put, to assure a flying wing doesn't get caught in its own lift circulation, make sure the "crotch" is DOUBLE the average chord. (The YB-49's ratio was only 1/3 of this.) When properly designed, our aircraft have no need for "black boxes" to maintain stability.



Our aircraft are remotely piloted, meaning flight loads are not transmitted to us; we navigate our models by their orientation in the sky, not by our perception of the horizon from inside the airplane. This can be an advantage.

'Wings are very fast, considering their wing loading, and flaps are a very effective way of getting them to slow down. Flaps can and should be used. Remember to keep the flaps close to the CG, and use flap/elevator mixing if your transmitter has this capability, otherwise you may need to make provisions for a mechanical device.

One item which we have not yet directly addressed here is wing twist. There are three methods for achieving the twist required for stabilty. The first is the simple method we use in making a foam core wing which results in a straight leading and trailing edge. The second method places most of the twist in the outer portion of the span. The third method, supported by Irv Culver, puts most of the twist at the wing root. This at first seems a rather strange thing to do, but it does optimize span loading and may provide other benefits. We'll discuss all three methods in a future article.

The YB-49 model which appeared in Richland was constructed of foam and covered with fiberglass and epoxy, spray painted aluminum. The fins projecting above and below the wing were made of lite-ply. Small diameter dowels extending from the lower fins were inserted in brass receiver tubes in the wing, holding them in place but allowing them to be knocked off during landing. The flight performance, as mentioned above, was sensational. Jack Northrop would have been proud!

SOURCES

Most of the information on the YB-35/YB-49 was found in an article by William R. Sears, a professor in the Department of Aerospace and Mechanical Engineering of the University of Arizona, and published in Aerospace America, July, 1987.

The article by Irv Culver should be required reading for all those interested in designing their own flying wings. It appeared in the TWITT (The Wing Is The Thing) Newsletter.

Looking at the plans for the Icarosaur, an RC flying wing sailplane with flaps and great flight performance, will yeild a wealth of information, some of it applicable to the construction of conventional models as well.

Wooldridge's Winged Wonders is also an excellent source of information about the Northrop designs and flying wings in general.

Seattle SoarHeads' YB-49 at the 1988 Richland Scale Fun Fly. Realistic and majestic in flight.