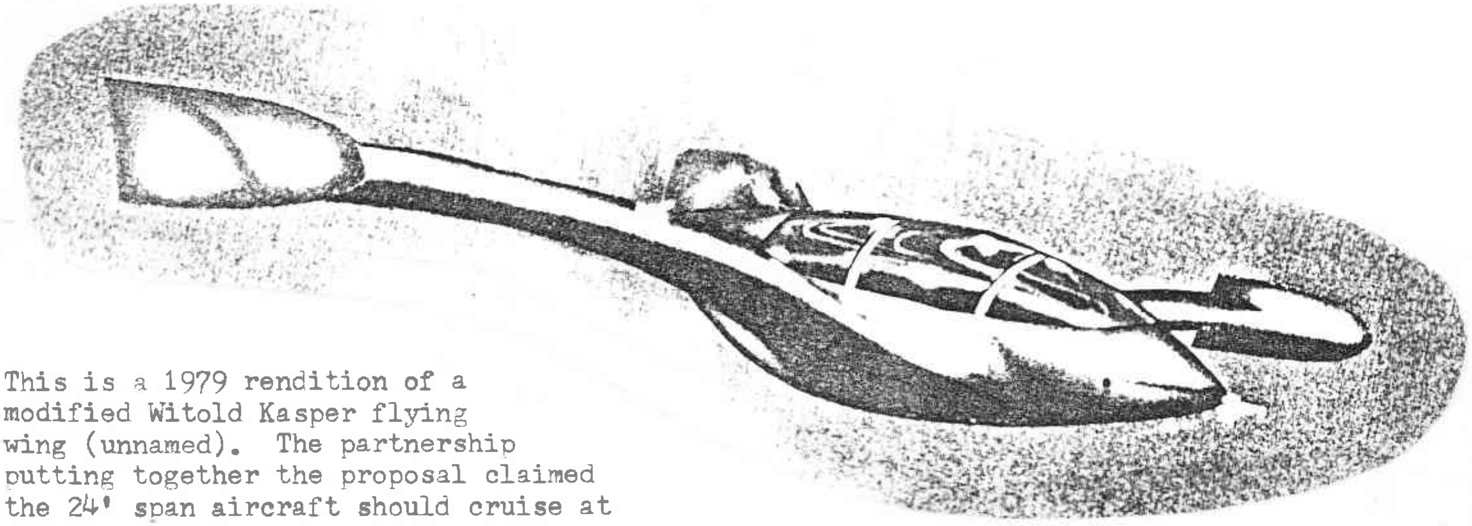
No. 55 JANUARY 1991

T.W.I.T.T. NEWSLETTER



This is a 1979 rendition of a modified Witold Kasper flying wing (unnamed). The partnership putting together the proposal claimed the 24' span aircraft should cruise at about 300mph on a 100 hp pusher engine.

For more information on how this team proposed to get this project off the ground, see page 5 of this newsletter.

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T.W.I.T.T.
(The Wing Is The Thing)
P. O. Box 20430
El Cajon, CA 92021

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Subscription rates are $15 per year for U.S. mailings and $19 per year for foreign mailings due to higher postage rates.

Next TWITT meeting: Saturday, January 19, 1991 beginning at 1330 hrs at hanger A-4, Gillespie Field, El Cajon, Calif. (First hanger row on Joe Crosson Drive - East side of Gillespie.)

PRESIDENT'S CORNER

Well, I hope everyone had a pleasant holiday season with lots of good food, gifts and time with your families. Mine was quite relaxing, and I was able to get a lot of work done on reorganizing the newsletter cover and publishing techniques.

Now that you have had a chance to put together your "centerfold", we hope you enjoyed this variation to the usual newsletter format. Perhaps the drawing will inspire some of our modeling members to get more information on the Horten designs and build some scale models.

Since we didn't have a meeting in December there isn't much to talk about this month. I will to talking with Phillip Burgers, Marc dePiolenc and Jerry Blumenthal over the next several weeks about some new ideas they have for TWITT. These will be published as we work out details of their implementation.

I would like to thank all of you for making 1990 a successful year for TWITT. Your confidence in our organization is attested to by the continuing membership level of about 115 members. The worldwide nature of this membership also shows we are reaching the widest possible spectrum of aeronautical talent of most any aviation oriented group. Keep us informed of your latest projects as they progress in 1991. HAPPY NEW YEAR and let's make 1991 even better.

Andy

JANUARY PROGRAM

Two possible speakers for January were unable to make it at the last minute due to higher priority business. Therefore, this month's program will consist of a New Year's Model building contest similar to the annual birthday party's. We have several very good examples of what can be done from this year's John Street Aeronautical Society gathering. This is your chance to show some creativity and ingenuity in producing a "wing" of unique concept and design.

There will also be several videos of model wings during initial test flights and some footage of the XB-49 and other flying wing aircraft.

If attendance is good the raffle prize will be a 450 Stearman ride provided by Addison Pemberton similar to the P-51 ride which Mark Motley won last year. He really enjoyed it. Otherwise we have several other valuable items which can be substituted based on overall attendance.

We will also be discussing some proposals on plans for TWITT's activities during the new year. Come and give us your ideas too.

LETTERS TO THE EDITOR

There is only one letter we decided to publish this month since it asks some leading questions of a technical nature that some of our members should be able to answer.

Jan 1, 1991

TWITT

I would like to resubscribe to the newsletter, and I am also enclosing a few items which perhaps your library does not have.

I also enclose a copy of my 1989 letter asking if you could provide a copy of the Van Dam article - no reply from you - I recall seeing a statement in TWITT that copies could be made at reasonable cost, however, I also know there is a limit to volunteer activity.

The 8-H-12 section has been mentioned again recently in regard to unpredictable control moments. In the article I am enclosing you will see that Kasper used that section, although later he recommended the FX05-H-126. I recall that Kasper told me or showed me that he had filled in the upper cusp of the 8-H-12 in the elevon area, I assume to solve the problem. I have not seen any reference in TWITT to the 'anti-anti-servo tab' which Kasper used to reduce adverse yaw - the tab goes up when the elevon goes down, reducing drag, and goes up when elevon goes up, increasing drag; it also varies elevator control forces.

In TWITT No. 4, Irv Culver gives an approximate rule for preventing tumbling - i.e. D should equal or exceed 2C. If this is simplified by assuming no taper, then this is equivalent to arctan of sweep equalling or exceeding 4/AR. Examples: AR=6, Sweep=33.7; AR=12, Sweep=18.4; AR=18, Sweep=12.5.

In TWITT No. 30 in the Weyl article Figure 8 gives stability as a function of sweep and aspect ratio. This table is also shown in modified form on Page 609 of Stinton's <u>The Design of the Aeroplane</u>. You will note that the Culver formula places all examples well into the unstable area. The Weyl diagram refers to untwisted wings, but Weyl says 'a substantial amount of wash-out does not constitute a complete cure.' Can you clarify this?

Another question concerns Culver's 'optimum twist distribution for a swept-back wing.' Does this distribution include both a factor to correct for change in basic lift distribution due to sweep, and a factor to provide longitudinal stability? It seems to be more than just a correction for taper. Can the loss of lift shown at the centerline in his diagram be compensated for by a widened center section with less twist than he calls for - i.e. wider chord, deeper spar at the inner 30%, something like a airliner wing. Such a planform could resemble the Horten solution for the 'middle effect,' and has structural advantages.

William Heijn
140 Leavenworth Street
San Francisco, CA 94102
(415) 673-9909

(Ed. Note: As of publication date we are trying to locate the Van Dam article in the library files, but have not yet found it. As was noted earlier, the library needs organizing so we can perform these types of services better. We apologize for the delay. Perhaps Todd Hodges would be kind enough to send us another copy of the article. We are also pulling together the other articles you requested in your 1989 letter. As for your questions, we hope that some of them can be answered at this month's meeting or that some of the members who have the answers will send them in so that the entire membership can benefit from them. How about it folks? Give us your best input on this one.)

The following was sent to us by Sylvester Benbough of Spring Valley, CA, who said it was sent to him by The Smithsonian. It is an article from the March 1932 Popular Aviation magazine and is reproduced here as it was originally published. However, the piece did not include any photos of the flying wing.

Lieut. W.A. Cocke Breaks Soaring Record

"Lieut. William A. Cocke, United States Army Air Corps, shattered the world distance and endurance record for gliders after flying twenty-one hours and thirty-six minutes in his yellow "Nighthawk."

"He created the new world distance record with approximately four hundred miles, the former record being 283.22 miles held in Germany. The previous endurance record made by Ferdinand Schultz in Germany was fourteen hours and seven minutes.

"Cocke established his record in Honolulu, December 18. His flight was made in the national glider meet competition, under the auspices of the National Aeronautical Association.

"Cocke is a second lieutenant of the 18th Pursuit Group, Air Corps, United States Army, Wheeler Field, Hawaii. He received his primary aviation training at Brooks Field and his advanced training at Kelly Field, San Antonio, Texas. After his graduation from this advanced training center in February, 1930, he left for his new station at Wheeler Field.

"The young flyer is also a designer. He built the 'perfect flying wing,' as his associates call it. Each day for months during off-duty hours Cocke tugged his glider from its shelter and spent much time long after day ended working on his discovery.

"He perfected a glider which has no tail at all. By doing this he gave pilots' greatest enemy--wind resistance--a severe blow.

"'It has no exterior appendage, no tail piece,' he explained. 'The purpose of this is to decrease the parasitic wind resistance; in other words, that resistance which contributes nothing to the buoyancy of the plane.'

"Even aviation, with its spectacular combat acrobatics, military maneuvers and aerial warfare, becomes monotonous. 'Not that I don't enjoy it,' Cocke admits, 'but I just turned to gliding for new thrills'"

"As a result of his quest for a new thrill, Lieut. Cocke holds the world glider record.

AVAILABLE PLANS/REFERENCE MATERIAL

Tailless Aircraft Bibliography
by Serge Krauss
Cost: $20
Order from: Serge Krauss
3114 Edgehill Road
Cleveland Hts., OH 44118

Horten 1C construction drawings with full size airfoil layout. 30 sheets 24" x 36" with specification manual. Price: $115.

Horten Newsletter
Cost: $5 per year for US/$7.50 foreign
Order from:

Flight Engineering and Developments
2453 Liberty Church Road
Temple, GA 30179
(404) 562-3512

The following was found in the Los Angeles Times *newspaper on about May 4th or 5th. Hopefully someone from TWITT will be able to provide some help.*

RESTORING '40s Northrop N9MB Flying Wing, need experienced volunteer woodworkers. Saturday work only. Call David Murray at (818) 369-8056 for details.

FLYING WING SAILPLANE PLANS AND KITS: Two time-proven, 13m homebuilt designs suitable for the novice pilot. Build either the MONARCH "F" ULTRALIGHT (19 to 1), or the PIONEER II-D (35 to 1) sailplane. Info packs $8 each, or $15 for both.

Marske Aircraft Corp.
130 Crestwood Drive
Michigan City, IN 46360

ADDITIONS TO TWITT LIBRARY

The following two items were donated by Bill Chana, Aviation Consultant in San Diego, CA.

Roskam, Jan, "Flying Wings - Advantages and Disadvantages of Tailless Airfoil Systems. They're Not For Everybody," Aircraft Design, October, 1990, pp. 44-48.

Chana, William F., "High Speed V/STOL - The Answer To Congestion?" AIRLINERS - The World's Airline Magazine, Fall 1990, pp. 26-28.

William Heijn submitted the following items:

Kasprzyk (Kasper), Witold A., Cross-Country Flying in High Performance Sailplanes, 1957.

The SKB-1A Tailless Sailplane, (author & date unknown).

"Sportsman STOL: NASA Predicts Mod Design Could Reduce General Aviation Fatalities by 20%", Western Aircraft Dealer's Monthly, July, 1986, p. 16.

Fredericks, Pierce G., "Where is That Plane Going?," Science Digest, April 1986, p. 88.

OBITUARY

We are sorry to announce that a fellow TWITT member, Bob Peck, passed away on January 7, 1991. He had a heart attack in mid December and apparently never fully recovered. Bob had been a solid supporter of the TWITT concept, and had contributed to the development of flying wings with his Genesis radio control glider which he marketed through Peck Polymers. He will be missed by all of us here in San Diego, since he was regular at the meetings.

The following article was extracted from the October 1990 issue of R/C Soaring Digest.

On The Wing

by B^2

Some time ago we mentioned our own tailless project, a 'wing for F3B, and promised an update on our progress. Following several flights of our current design we are now able to give an informative report.

As is the case with many projects, our goal with Project Penumbra is not so much to come up with something entirely new and earth shaking, but more to take existing information from a variety of sources and come up with a design which (1) is within our capabilities to construct, (2) can be flown well with but a reasonable increase in flying skill, and (3) will provide excellent performance in all flight regimes once sufficient skill is acquired. We are also eager to learn more about flying wing structures and aerodynamics. It is hoped that the eventual design will be a competitive F3B machine.

Conventional designs and swept flying wings are rotated in pitch by control surface movement behind the CG; the nose is raised by applying a downforce. Project Penumbra began with the idea that a swept 'wing with narrow chord and large sweep angle could have its elevator in front of the CG. This is advantageous in that the force needed to change pitch is in the direction of the desired change; thus down elevator increases lift over the center of the wing and raises the nose. Due to the extreme sweep angle needed and the fact that what is really being considered in this case is a canard (in general a poor soaring configuration), the idea was abandoned.

We knew from experience that plank designs would not be competitive in the F3B environment as they tend to be one speed airplanes. We also knew that trim drag had the potential of reducing the speed range of a swept wing, just as with a conventional tailed sailplane. We wanted our design to have a broad speed range. Our experience with the positive moment coefficients of our planks, and tailed aircraft we had flown, pointed to the use of an airfoil with a pitching moment of close to zero. Very little trim would be needed at high speed, and the trim change needed for thermalling would actually be beneficial to stability and the lift distribution.

Construction of our first swept 'wing was started. It featured a 9% symmetrical Quabeck section over the entire span, used 1 degree of twist, elevons, and double spar. One week later we had a pink foam 'wing covered in fiberglass. Built before we had our vacuum bagging equipment, it turned out so heavy and so crude that we've never gone to the time, trouble, and expense of putting the finishing coat of epoxy on it. We also realized that we had more of a slope racer than a thermal machine, and it has remained flightless for more than two years.

In retrospect, it should have been obvious that the symmetrical Quabeck section was not appropriate as it would not be able to provide a large amount of lift. About this time we received some information on the EH series of profiles created by John Yost. These sections are cambered, ranging from 1% to 2%, have high lift capability, and yet have a pitching moment of nearly zero. It looked like we had access to a wing section that would work well.

The 1989 MARCS Symposium featured Walter Panknin talking about his "Flying Rainbows." Walter was quite effective at committing us to our concept. Home from Madison we immediately set up our vacuum bagging system. We laid out our constant chord foam cores, installed Walter's spar system, applied several layers of fiberglass and sucked it all down with our GAST vacuum pump. A few nights of work on the control surfaces and our creation was finished. Compared with the previous 'wing, this one was beautiful: accurate, light, and glassy smooth.

First flight of Penumbra.1 were hand launches over wet grass on a cold morning. Several hand tosses indicated that much weight could be safely removed from the nose, but running across the field as fast as possible and throwing the 'wing as hard as possible still resulted in its diving to gain speed. The ship was finally roughly trimmed out with elevons in neutral, and we elected to winch it up.

Not only was it cold but the fog which had saturated the grass still lingered overhead. Earlier flights that morning with our Blackbird 2m had resulted in "out of sight" performances, so we were careful to limit the launch height of our new 'wing, particularly since the only paint on her was grey primer. We pulsed the winch line tight and threw her hard. She went up on the line with no problems. Turns were made in both directions. There was absolute silence during an overhead pass. Two 360 degree turns brought her into a long shallow approach. Water sprayed into the air from the entire leading edge of the wing, but she was on the ground in one piece. We decided to pack up and go home with Penumbra.1 still in one piece and wait for a more conducive flying day.

Two days later, while cleaning Penumbra.1, it was discovered that during that single flight the upper surface of both wings had failed in compression! This probably occurred during launch. It suddenly dawned on us that fiberglass is not so good in compression as balsa, and that Walter's spar system was for a balsa sheeted wing. We were pleased, however, that Penumbra.1 had not only continued to fly but had flown so well, even with major structural failure.

Constructed of pink foam and fiberglass, Penumbra.2 is aerodynamically identical to Penumbra.1; structurally, two 3/32" plywood vertical web spars in each wing reach past the previous point of failure. Penumbra.2 has now been completed and winch launched several times.

Results of these first flights have been quite satisfying. Although air speed is very high, Penumbra.2 gives obvious indications when in lift, and has been thermalled. Although a bit pitch sensitive, aileron control is quite positive, and the flaps, when deflected 80 degrees, bring her to a nearly complete stop. The airframe is extremely strong, as evidenced by several hard "landings."

On the negative side, we still haven't entirely eliminated all of the structural problems, as on one launch (the highest) both wings appeared to flutter. This most likely came from the control surfaces. Also, launch height is not nearly so high as it could be. Improved height off tow will come with proper CG and towhook locations, along with eliminating the flutter and achieving higher speeds.

We are still at the "proof of concept"

stage, yet all of the goals we set for Project Penumbra are being met. Although our construction techniques have been challenged, the project falls well within our capabilities.

Penumbra.1 proved easier to fly than expected, and it was immediately obvious that the design had great potential. Penumbra.2 has confirmed that notion. Our goal of learning more about structures and aerodynamics is being fulfilled beyond our expectations, and evaluation and further evolution of the design will continue.

We've drawn some sketches of the structure of Penumbra.1 and Penumbra.2. While these drawings are probably not sufficient for construction of a competitive machine, they do include information on materials used in both versions and show the points of failure on Penumbra.1. We'd be happy to share them with anyone sending us $1.00 in postage. Full sized plans for Penumbra will eventually be available from our plan service, B^2 Streamlines; watch for an announcement in RCSD.

Bill & Bunny Kuhlman
P.O. Box 975
Olalla, WA 98359-0975

(Ed Note: B^2 are also members of TWITT. We hope that they will send us a copy of their sketches so the group could take a look and perhaps help them with some of the structural and/or aerodynamic problems they are encountering. The group which meets each month has a number of active modelers in it who are also very interested in the concept of flying wings. This could be an unbeatable combination in producing a competitive F3B machine. How about it B^2?)

ODDS & ENDS

The John Street 'Aironutical' Society met at the Wiberg-Fronius residence and held its annual New Year's Day glider model design contest. Ed Lockhart built and flew a "Sellers" (three wing) that had diffuser tips and negative stagger. The center jig support was reshaped to become the fuselage.

Hernan Posnansky won the only prize, a book on gliders, for his "excellence in design," a tailless wing with an elliptical plan form.

Champagne and breakfast were provided by June Wiberg. Doc Sloan again fired his carbide powered canons - what a way to celebrate the inbound new year.

COVER - This month's cover picture came as part of the package from William Heijn of San Francisco, CA. Included below are excerpts from the October 4, 1979 letter which accompanied the artist concept drawing. We have not included the names of the partnership since this information is quite old and it appears obvious the project never reached a successful conclusion.

"As a fellow aviation enthusiast, we'd like to introduce you to quite a new concept in flying - radically different, but hardly radical.

"We are attempting to continue modifications on the airplane designed by Witold Kasper. It's a dramatic departure from conventional aircraft, but when operated by a knowledgeable pilot, it is dramatically safer, too.

"Our plane has a 24' wingspan and will be capable of some rather astounding feats. With a 100 horsepower pusher engine and a very natural wing profile, cruising speed should be about 300 m.p.h.? But the Kasper plane can retain full control at almost no forward speed. So landings require very short runways and are still quite safe. Take-off speed of 40 m.p.h. or less makes it possible to take off where few conventional aircraft would dare. It is also completely stable, righting itself gravitationally, by design, when the controls are released. An earlier glider version of the plane has an FAA certification permitting, 'Any form of aerobatics - including tumbling - with no altitude restrictions.'

"Mr. Kasper developed the concepts for his flying wing after years of designing traditional airplanes. An important area of study was one he felt had been overlooked: he observed the flight of birds. Their natural aerobatic abilities contributed many modifications to the plane, and indeed it's bird-like in many ways, particularly in its efficiency.

"When completed, the flying wing will be able to travel further and faster on less fuel than any comparable conventional plane.

"The plane has safety and economy going for it already. But also inherent in its design is a sheer joy of operation; we know pilots around the world will appreciate its design the moment they're behind the controls."

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Number of data points for lower surface:  27
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  2        -0.08      5.47     -0.06      4.49
  3        -0.01      5.97      0.00      4.20
  4         0.10      6.46      0.07      4.03
  5         0.25      6.94      0.16      3.81
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  7         1.25      8.82      0.39      3.40
  8         2.50     10.20      0.54      3.21
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 27         0.00      0.00    100.00      6.75
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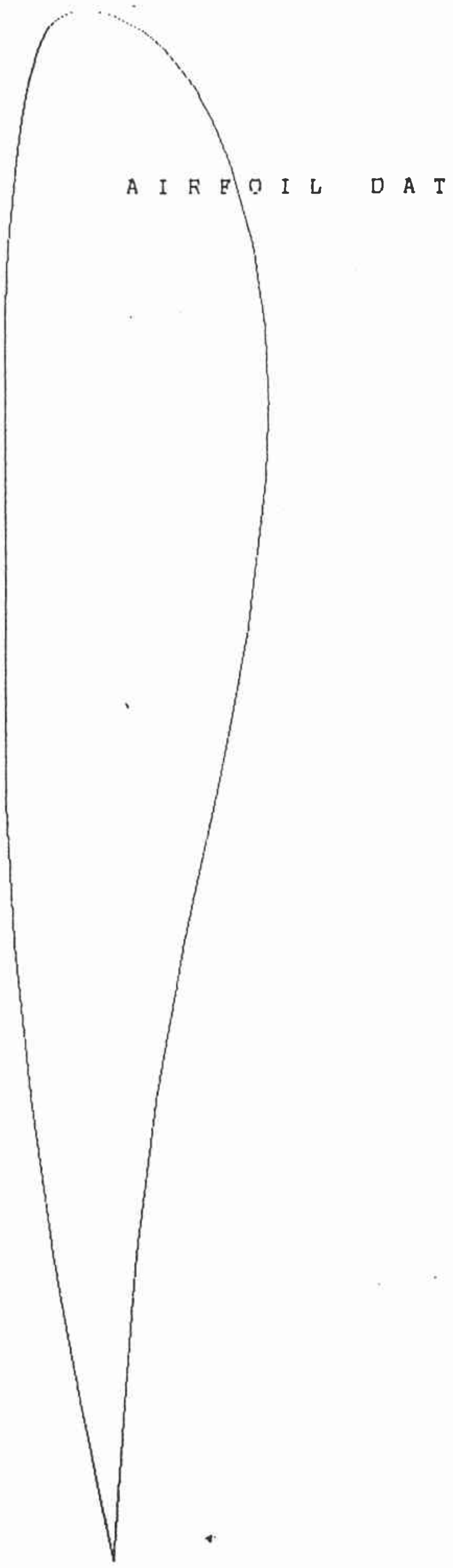
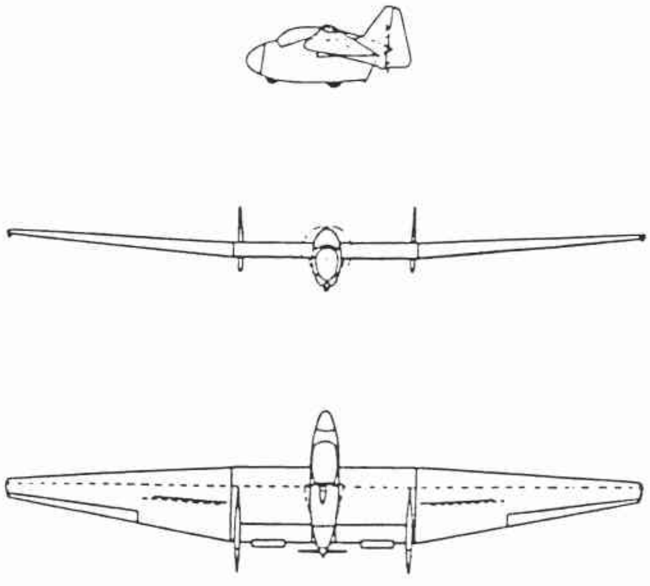
This was submitted by Alan Lewis of Australia.

He said this airfoil has worked okay in at least 5 designs with no twist.

(Ed. Note: If anyone knows anything more about this airfoil or uses it in a model, etc., please let us know.)

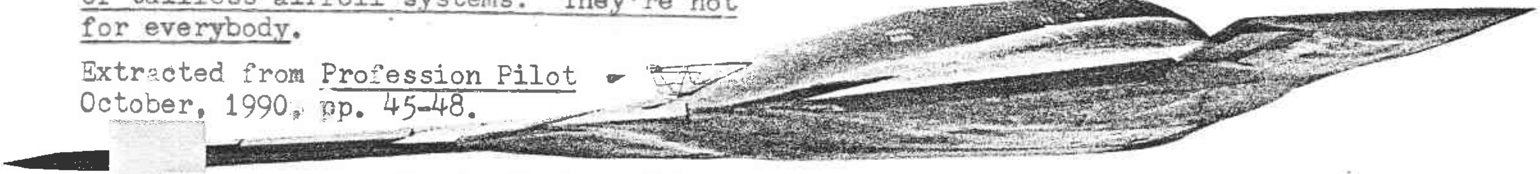




Fauvel AV-45

Flying Wings - Advantages and disadvantages of tailless airfoil systems. They're not for everybody.

Extracted from Profession Pilot October, 1990, pp. 45-48.



By Jan Roskam, PhD
Professor of Aerospace Engineering, University of Kansas

FLYING wings have been around for a long time in one form or another. The first flying wing glider flew in 1906! With that in mind, why is it that flying wings have not secured the foothold in aviation gained by more conventional looking planes?

The purpose of this article is to review some of the pros and cons of flying wing designs. The advantages of the flying wing are summarized as follows:

- Aerodynamic efficiency: They are more efficient due to the absence of components such as a fuselage, a horizontal tail and a vertical tail.
- Efficiency from a weight viewpoint: All the payloads, systems and structures are in the wing itself, thereby reducing the root bending moment.
- Very low observables: A flying wing is inherently more difficult to detect by optical means or by radar than a conventional airplane. Flying wings 'expose' less reflective area in most directions. The vertical direction is an exception to this.

As might be expected, there are disadvantages associated with flying wings. Some of these disadvantages are the reason(s) why flying wings have not been a popular choice for production airplanes. The following practical constraints illustrate this point.

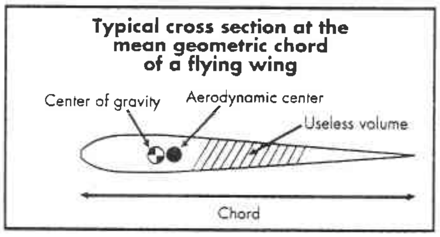
Human Body Size

Let us try to design a flying wing passenger airplane for 150 passengers. If these passengers are to fit inside the wing with the normal cabin amenities, a major problem arises. Assume that an acceptable minimum cabin internal height (floor-to-ceiling) is 6.5 ft. Allowing 1.5 ft for total structural depth below the floor and above the ceiling, the external thickness of the flying wing will be 6.5 + 1.5 = 8 ft. In a subsonic airplane, a typical airfoil thickness ratio is 12%. Therefore, the local chord length will be 8/0.12 = 66.7 ft. It is further assumed that this local chord is in fact the mean geometric chord of the wing, that the wing aspect ratio is eight (typical of transport aircraft) and that the wing taper ratio is 0.4. The required wing area can now be calculated: S = 31,602 ft^2. This is a very large area indeed, especially when compared to a wing area of about 2000 ft^2 for a more conventional design. Clearly a flying wing is not a suitable configuration choice for a medium-sized passenger airplane. Its wetted area will be way too high and therefore the low drag advantage can't be realized. However, for a very large airplane the flying wing configuration could make sense.

Weight and Balance

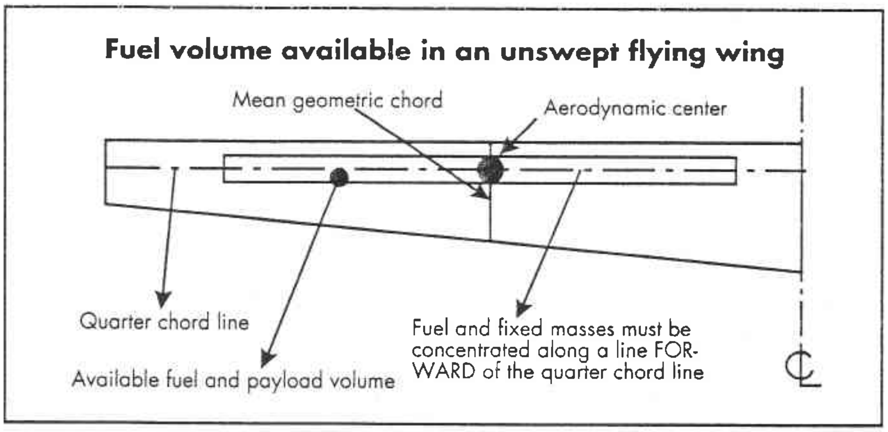
Let's assume that we want to design an unswept wing of any size. Figure 1 shows a typical cross section of this wing. Note the center of gravity and the aerodynamic center locations: the cg must be forward of the aerodynamic center if the design is to be inherently stable. Figure 2 shows a typical topview of such a flying wing design. Note again the relative locations of the cg and the aerodynamic center. The fact that the cg has to be so far forward on the planform leads to major weight and balance problems. Clearly both the empty weight cg and the loaded weight cg must be located forward of the quarter chord point. Therefore, not much room is available to put fuel and payload into the wing. Additionally, there is a lot of useless volume behind the quarter chord point (Figure 2).

There are two ways to solve this problem — sweep the wing and/or make the flying wing inherently unstable and equip it with an automatic stabilization system (Figure 3). The



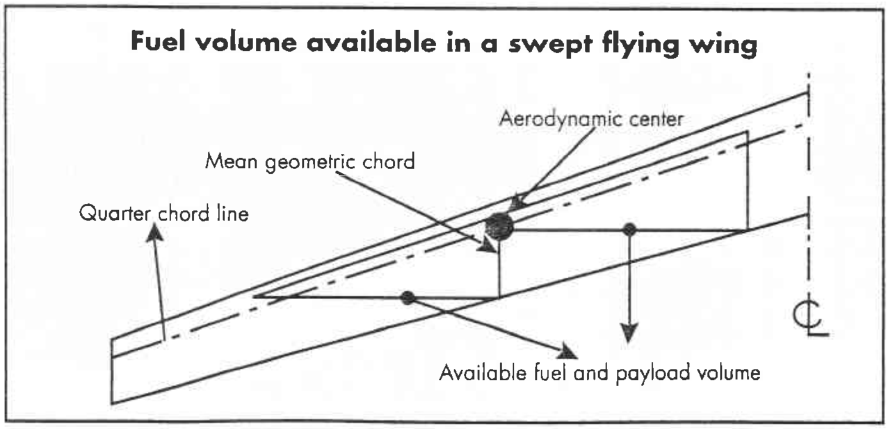
Typical cross section at the mean geometric chord of a flying wing

Figure 1



Fuel volume available in an unswept flying wing

Figure 2



Fuel volume available in a swept flying wing

Figure 3

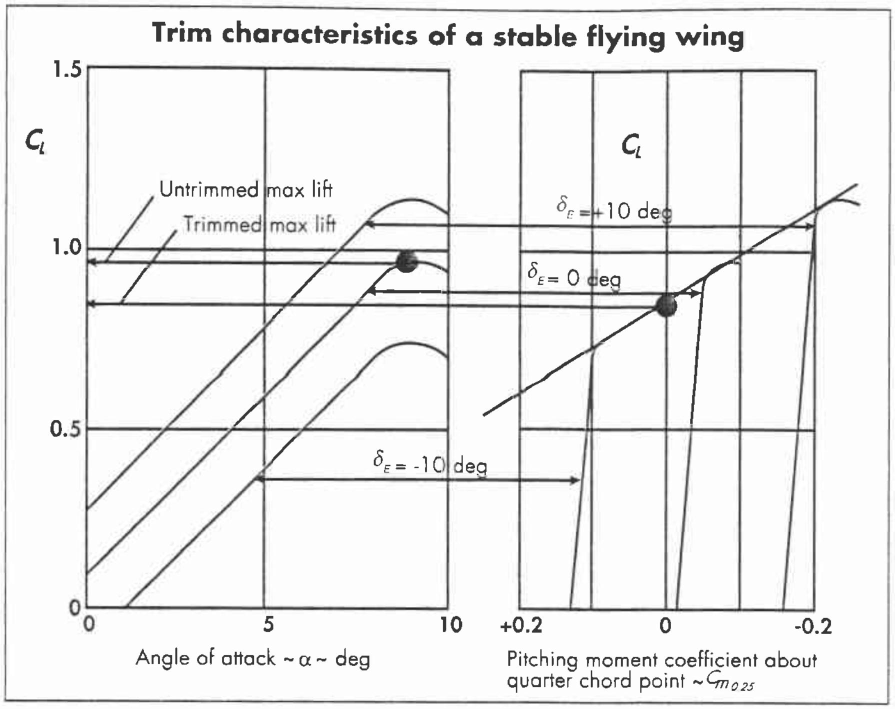


Figure 4

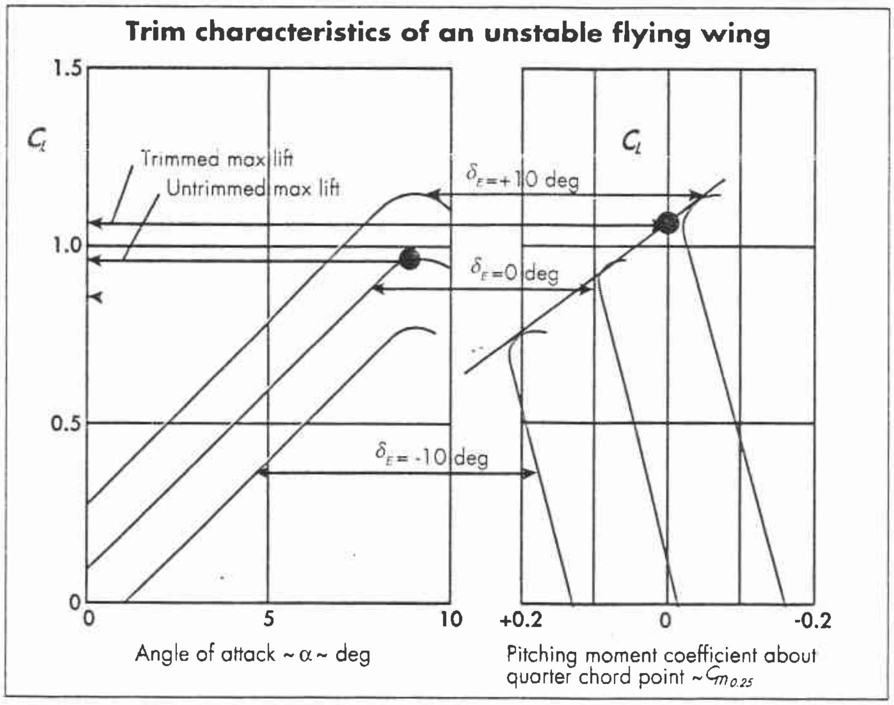
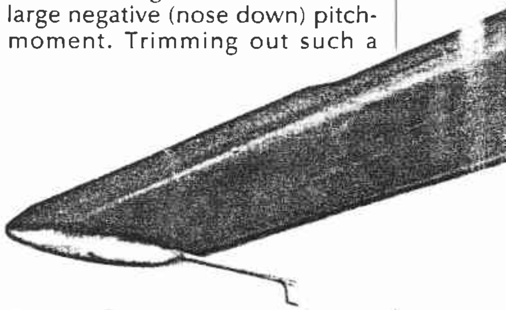


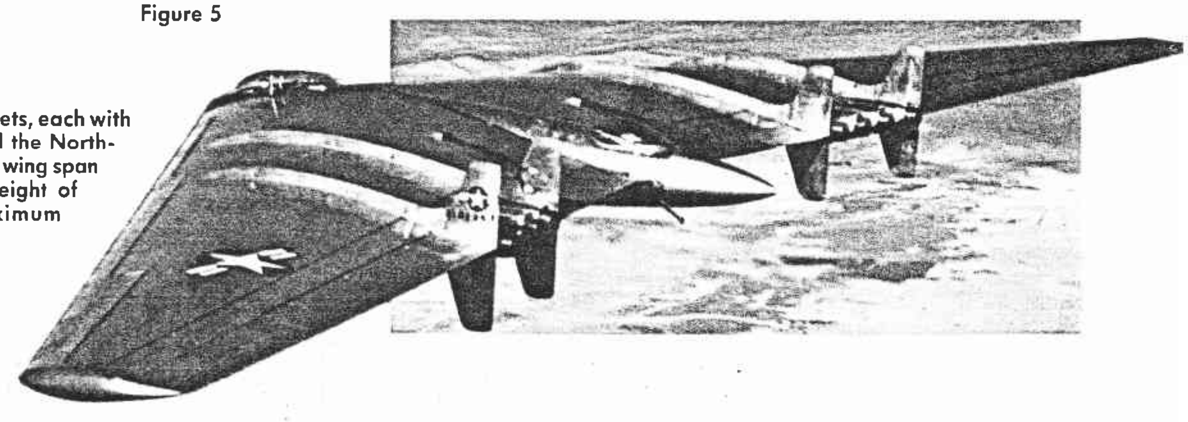
Figure 5

second way will not be discussed here. (The Northrop B2 bomber uses this design feature—an inherently unstable wing.) Note that this gives enough flexibility to arrive at a reasonable allocation of masses and volumes. However, by sweeping the wing, the weight will go up because of the additional amount of torsion load which needs to be supported by the structure. In a low subsonic design this is a weight penalty. In a high subsonic design it is not because the wing needs to be swept to keep compressibility drag from becoming too large. The Northrop B35 and YB49 both used this design feature.

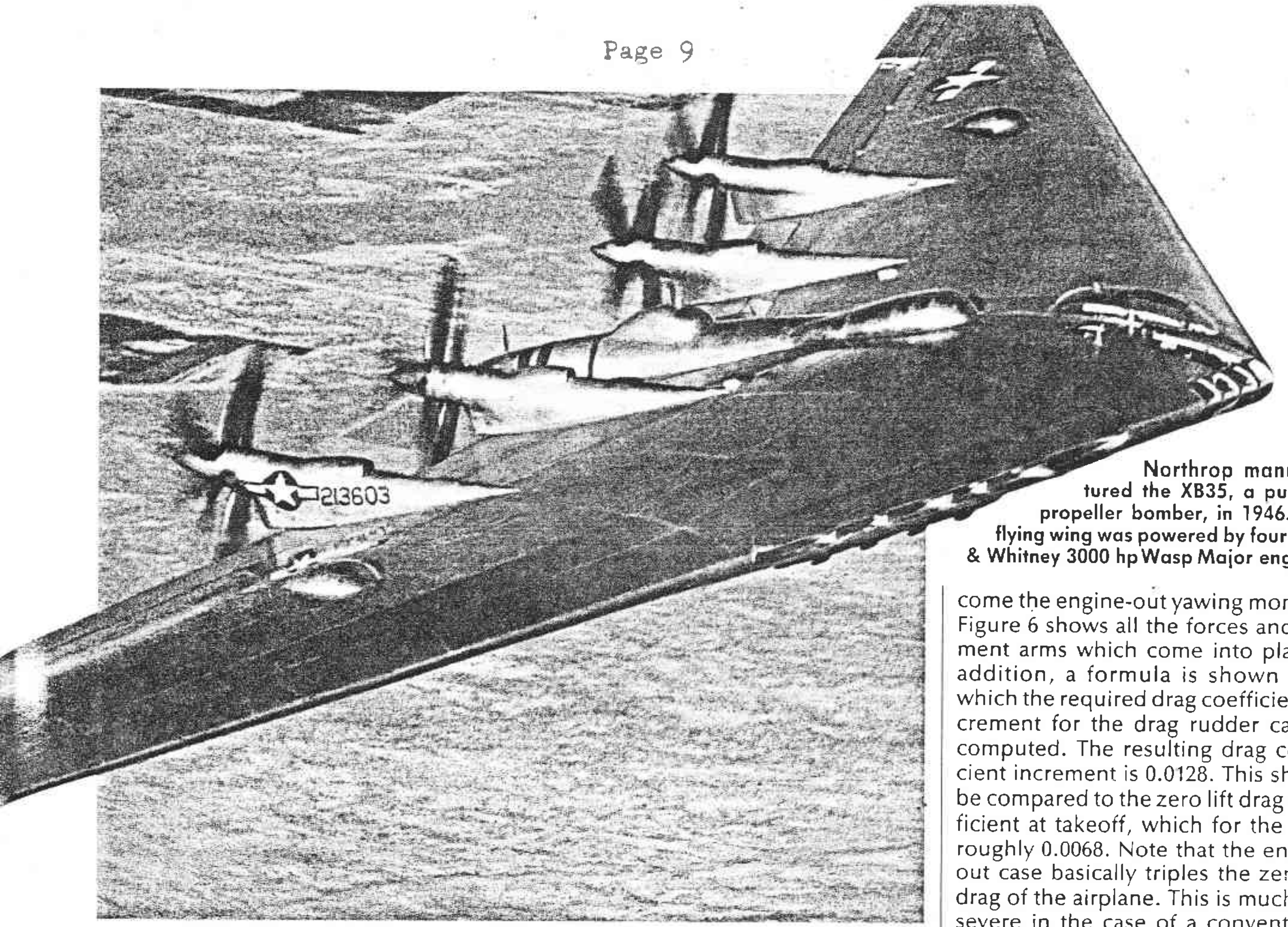
Trim at high lift

Conventional airplanes use flaps for high lift. Most high lift devices result in a large negative (nose down) pitching moment. Trimming out such a negative pitching moment without a tail is not practical. The fundamental reason for this is the lack of 'moment-arm' of the trailing edge devices. Any trailing edge mounted high lift device tends to be self-defeating in a flying wing. The trimmed maximum lift is much less than the untrimmed maximum lift. Heavily cambered airfoils which give high lift at low angle of attack also have large negative pitching moments as a side-effect. Therefore, most flying wings use airfoils with very little camber and no or small flaps. Because flying wings tend to have a very large wing area they probably do not need flaps; their wing loading is so low that they can lift off without flaps. That is certainly the case with





Eight Allison J35A-15 turbojets, each with 4000 lbs of thrust, powered the Northrop YB49. The bomber had a wing span of 172 ft and a takeoff weight of almost 200,000 lbs. Maximum speed was 425 kts.



Northrop manufactured the XB35, a pusher-propeller bomber, in 1946. This flying wing was powered by four Pratt & Whitney 3000 hp Wasp Major engines.

the Northrop B2 which has a wing loading at takeoff of roughly 48 psf. This compares to a wing loading of 120-150 psf for most conventional jet transports, indicating a factor of three difference in wing size. This is equivalent to a factor three in a requirement for high lift. The B727 has a maximum design lift coefficient (flaps down) of about 2.7. A comparable flying wing would need only about 0.9. Trimming out that magnitude of lift coefficient is feasible according to Figure 4.

If the flying wing is made inherently unstable, the trimmed maximum lift capability actually increases compared to the untrimmed case (Figure 5). Again, the B2 uses this feature.

Directional Stability and Control

A flying wing also runs into problems with its lack of directional stability, particularly at high speed. This problem can be fixed by adding vertical stabilizers to the wing. The YB49 used out-board mounted vertical stabilizers. Of course, when that is done, extra weight and wetted area are added. The vertical stabilizers would have to be relatively large due to the small moment arm.

That still leaves the directional control problem following an engine failure at takeoff. Figure 6 illustrates the problem and the way this was solved on the B2 (and earlier on the B35). A so-called 'drag-rudder' is used for directional control. This drag rudder is more or less like an aileron split into halves which can be opened up. By opening up the split trailing edge of the drag rudder in a differential manner a yawing moment can be generated. This yawing moment has to overcome the engine-out yawing moment. Figure 6 shows all the forces and moment arms which come into play. In addition, a formula is shown from which the required drag coefficient increment for the drag rudder can be computed. The resulting drag coefficient increment is 0.0128. This should be compared to the zero lift drag coefficient at takeoff, which for the B2 is roughly 0.0068. Note that the engine-out case basically triples the zero lift drag of the airplane. This is much less severe in the case of a conventional airplane.

Miscellaneous Problems

There are several problems associated with flying wings:

- Lack of pitch damping
- Pressurization of passenger cabin or cargo hold
- Evacuation in case of a crash

Lack of pitch damping: Flying wings lack inherent pitch damping. A conventional airplane has a lot of inherent

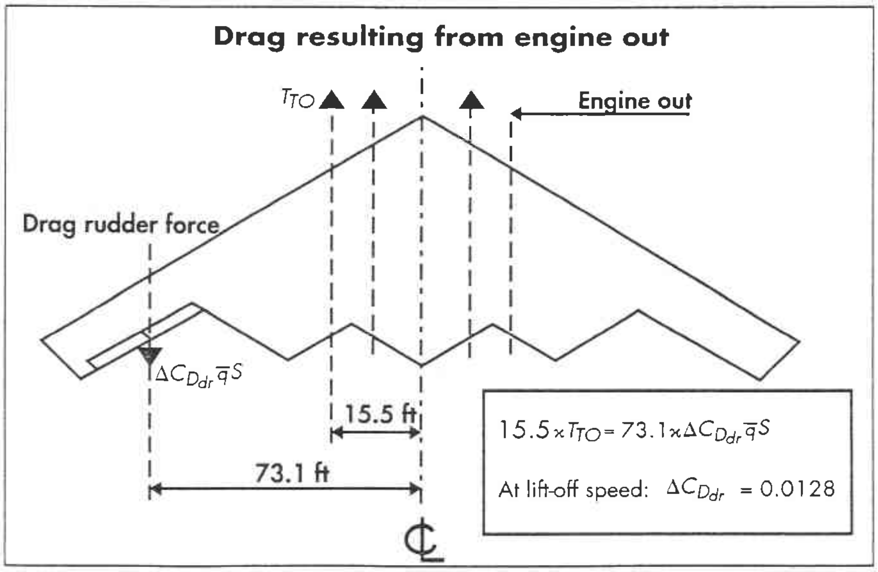


Figure 6

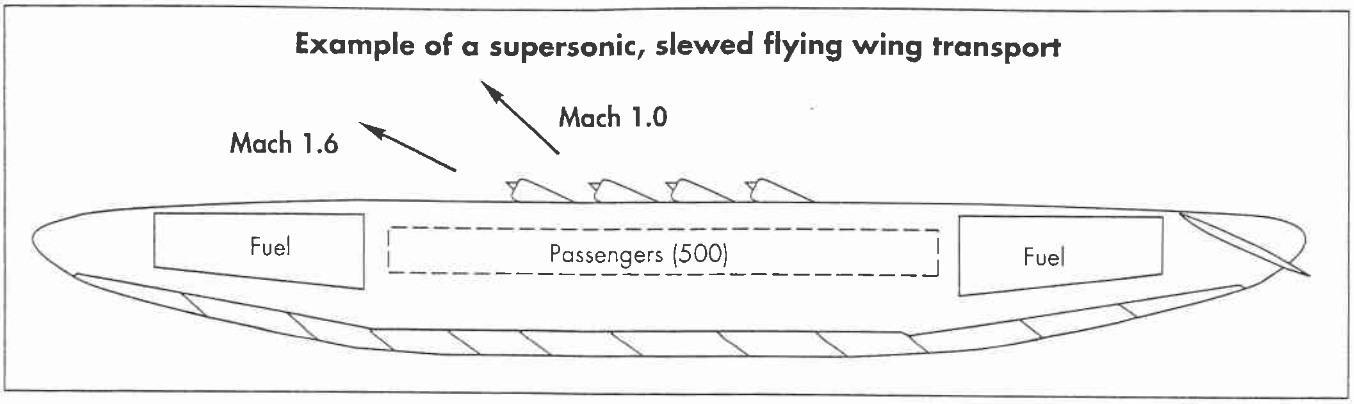


Figure 7

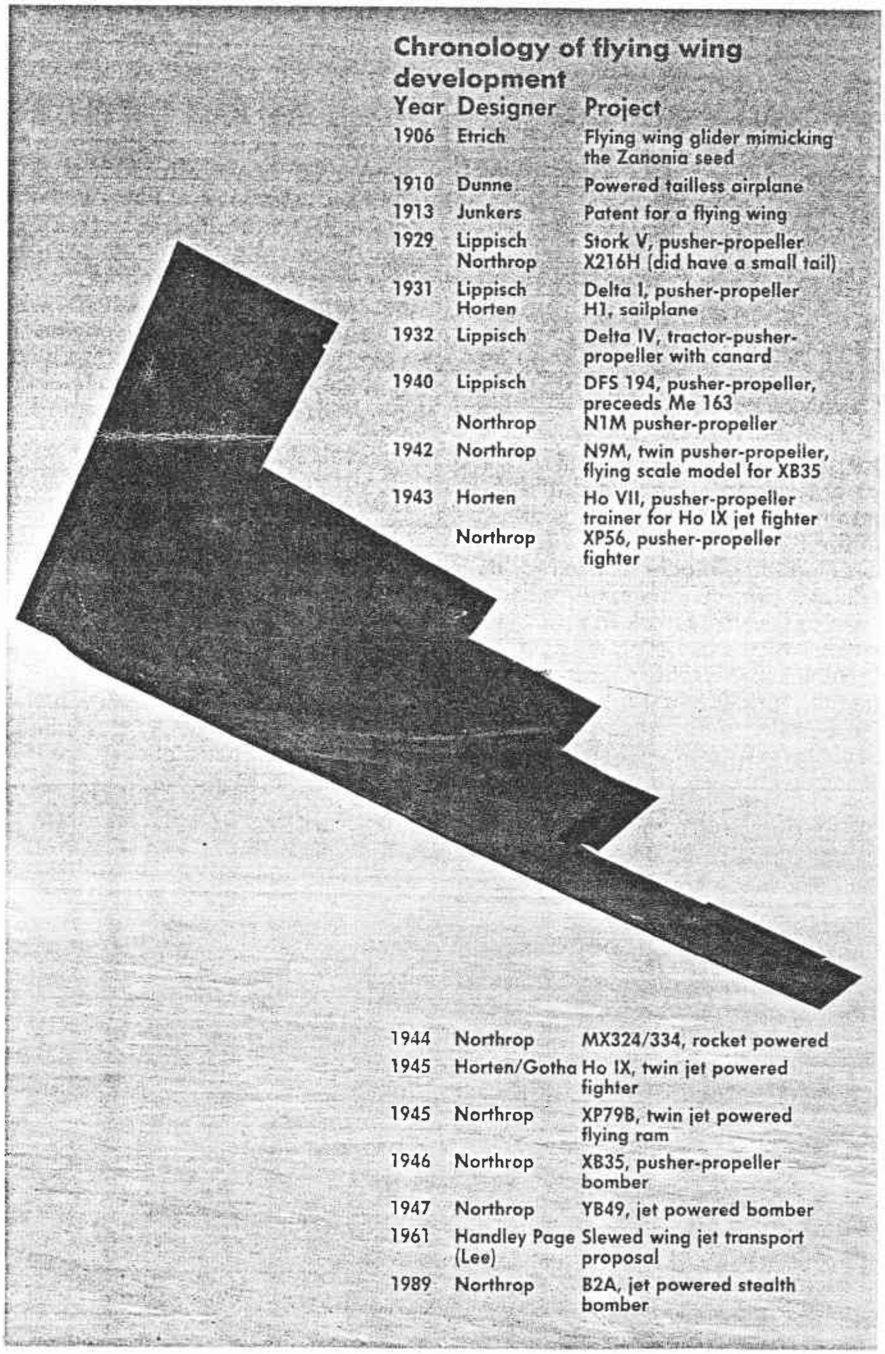
pitch damping because of two factors: tail area and tail moment arm. A flying wing has neither tail area nor tail moment arm. Flying wings therefore need some form of artificial pitch damping, obtained by deflecting trailing edge control surfaces in proportion to but in opposition of pitch rate. Again, the B2 uses this design feature.

Pressurization of passenger cabin or cargo hold: Because of the relatively flat shape of the upper and lower surface skin of a wing, it is not the best choice when it comes to withstanding pressurization loads. To counteract this, some form of curved internal structure would have to be arranged. It is believed that this causes a weight penalty compared to conventionally pressurized fuselages which have a circular shape.

Evacuation in case of a crash: In case of a gear-up crash, the only way to evacuate from a flying wing is through upper surface hatches. This can be arranged but will probably result in weight penalties. There is the additional problem of keeping the passengers away from spilling fuel.

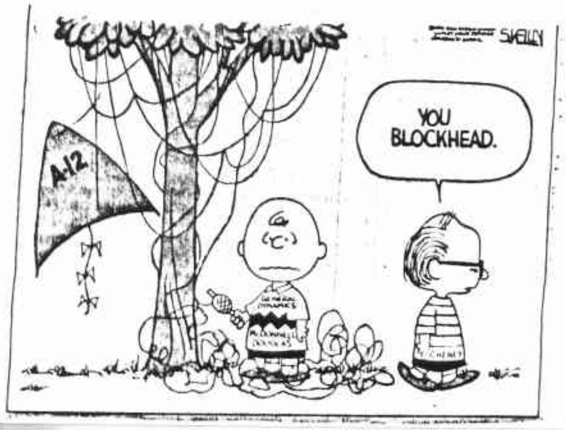
Just the ticket

Flying wings have a number of design problems which are inherent to the flying wing configuration. If the low observables reason is sufficiently compelling (such as the case with the B2), a flying wing can certainly be made to work. If the payload to be carried does not require a large internal height, the flying wing may be the right choice. Finally, a famous NASA scientist, R T Jones has shown that a slewed flying wing (Figure 7), compared to all other configurations, possesses very favorable lift-to-drag characteristics at supersonic speeds. For a 500 passenger, trans-oceanic, supersonic airplane, the slewed flying wing may be just the ticket.

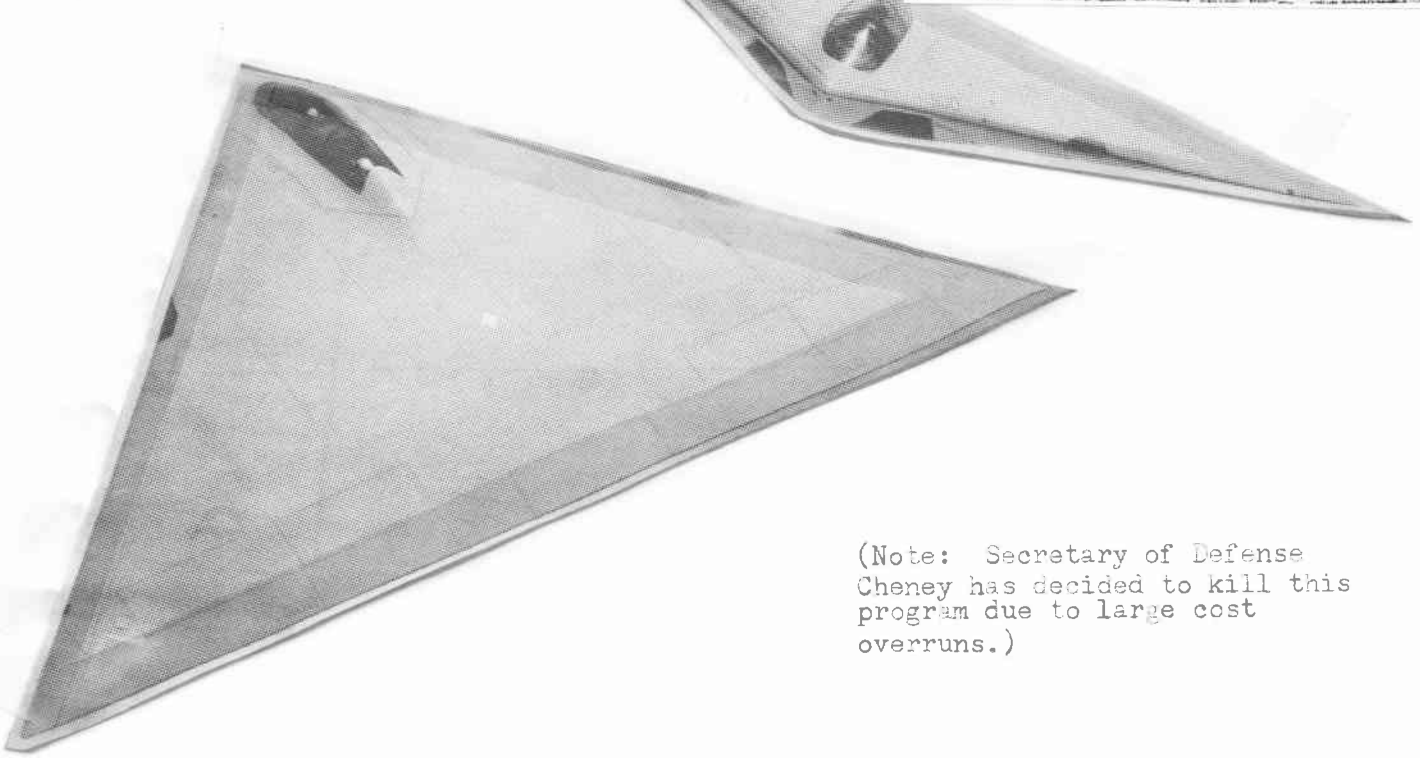


Chronology of flying wing development

Year	Designer	Project
1906	Etrich	Flying wing glider mimicking the Zanonia seed
1910	Dunne	Powered tailless airplane
1913	Junkers	Patent for a flying wing
1929	Lippisch	Stork V, pusher-propeller
	Northrop	X216H (did have a small tail)
1931	Lippisch	Delta I, pusher-propeller
	Horten	H1, sailplane
1932	Lippisch	Delta IV, tractor-pusher-propeller with canard
1940	Lippisch	DFS 194, pusher-propeller, preceeds Me 163
	Northrop	N1M pusher-propeller
1942	Northrop	N9M, twin pusher-propeller, flying scale model for XB35
1943	Horten	Ho VII, pusher-propeller trainer for Ho IX jet fighter
	Northrop	XP56, pusher-propeller fighter
1944	Northrop	MX324/334, rocket powered
1945	Horten/Gotha	Ho IX, twin jet powered fighter
1945	Northrop	XP79B, twin jet powered flying ram
1946	Northrop	XB35, pusher-propeller bomber
1947	Northrop	YB49, jet powered bomber
1961	Handley Page (Lee)	Slewed wing jet transport proposal
1989	Northrop	B2A, jet powered stealth bomber



A-6 Replacement?



(Note: Secretary of Defense Cheney has decided to kill this program due to large cost overruns.)

THE FUTURE OF CV MEDIUM ATTACK

The first public detailed disclosure of the highly classified McDonnell Douglas/General Dynamics A-12 *Avenger* program was presented at the 34th Annual Tailhook Symposium, 7 September 1990. Program manager for the Navy, RADM (sel) Larry Elberfeld, and the OP-05 requirements officer, CAPT Mike Currie, discussed the next-generation carrier strike aircraft scheduled to replace the A-6 *Intruder* in the medium attack role. Like the A-6, the A-12 is crewed by a pilot and bombardier/navigator, but the crew stations are in tandem differing from the side-by-side configuration of the *Intruder*. The *Avenger* is designed for the all-weather strike mission with additional subordinate duties of air-to-air warfare and reconnaissance. Ordnance, both air-to-ground and air-to-air, is primarily designed to be carried in internal bays, but the aircraft will have provisions for external carriage of stores. The A-12 will be able to carry more ordnance than the A-6, deliver it at a higher speed and do it more accurately with a myriad of sophisticated navigation systems. The aircraft is designed to have greater sustained and instantaneous turn rates than either the A-6 or F/A-18. Powered by two General Electric F412-GE-400 engines, the A-12 is designed for maximum use of low-observable characteristics while maintaining carrier compatibility.

The *Avenger* is designed to have double the reliability of the aircraft it replaces, while taking one-half the manhours to repair it. Ground support equipment requirements have been cut to a minimum, simplifying the squadron's deployment packup. Avionics are being supplied as contractor furnished equipment (CFE) instead of the now-common practice of delivering the aircraft and installing government furnished equipment (GFE) after the aircraft is in squadron service. In this way, the A-12 will not be a victim of black box hot switching as now practiced between squadrons getting off deployment with those just starting cruise. The only changes to current aircraft carriers will be to enlarge the composite repair shops in the intermediate maintenance departments (IMA), IMA benches added to include compatibility with the new computer aided support system (CAST) and addition of the tactical air mission planning system (TAMPS) in the intelligence center. Catapults, arresting gear and common support equipment will all be compatible with the *Avenger* without modification. With wings spread, the aircraft is slightly wider than an F-14 (with wings spread) and with wings folded, it is slightly wider than an A-6 (wings folded). Because of a shorter overall length, the deck multiple is less than an A-6.

Current plans are to roll out the first aircraft before the end of next year with first flight in early 1992 at Tulsa, Okla. Sea trials will follow a year later and the first fleet replacement squadron will accept its first aircraft sometime in 1994. Operational evaluation follows in mid-1995 with an initial operational capability (IOC) attained in 1996 or '97. The IOC is being driven by congressional budget decisions and will depend upon how many airframes are available for the first squadrons. If everything goes as scheduled, the first operational deployment on an aircraft carrier will be in late 1998. Current plans are to procure 620 airframes, with 20 assigned to each carrier air wing. Others will be assigned to RDT&E, training squadrons and the Reserves. Final phaseout of the A-6 is programmed for around 2005.