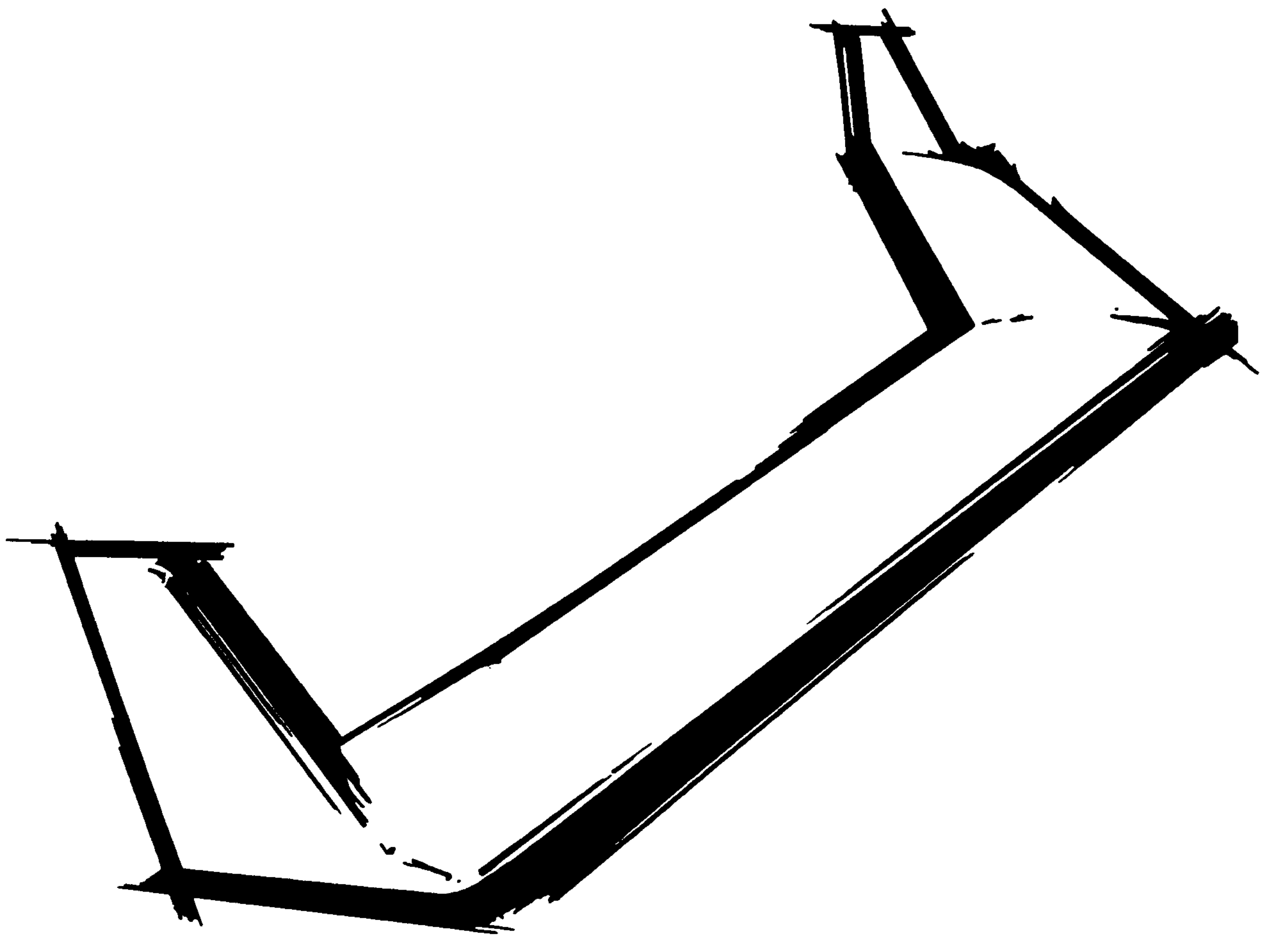
# ON THE 'WING...
*the book*



BILL & BUNNY KUHLMAN

# ON THE 'WING...
## *the book*

Bill & Bunny Kuhlman

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Dedicated to the memory of

Dr. Ing. Walter Panknin
(1944 - 1992)

## PREFACE

"On the 'Wing...," after more than four years, remains the only monthly column appearing in the modeling press devoted exclusively to tailless soarers.

"On the 'Wing... the book" is a collection of the articles which have appeared in RC Soaring Digest to December 1992, arranged in chronological order by date of publication. Those few columns which dealt with subjects not directly related to tailless sailplanes are arranged in a separate section.

We endeavored to achieve two goals during the editing process - making the text more readable, and updating the source listings. In addition to all of the diagrams, airfoil coordinates, and computer programs from the original RCSD columns, we have included additional and supplemental information.

Both the monthly column and this book owe their existence to Jim Gray, founder of RCSD, and Jerry and Judy Slates, RCSD's current editor and publisher. It was Jim who accepted our first six "On the 'Wing..." articles en masse, and then continued to support our writing. Jerry and Judy have been wonderful, continuing where Jim left off and enthusuastically promoting the idea of publishing "On the 'Wing... the book."
We cannot imagine a more positive experience than being associated with RCSD.

Our own fascination with tailless aircraft has never abated. If this book motivates or encourages another, our efforts in putting it together will be rewarded.

BILL & BUNNY KUHLMAN

Olalla
February 1993

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Published articles not directly related to tailless aircraft:



APPENDIX

## THE FIRST COLUMN

Our fascination with tailless aircraft of various kinds goes back several years and owes its beginnings to our acquiring plans for Dave Jones' "Raven" from Model Builder and seeing a photo of Curt Weller's "Elfe 2" in Model Aviation at about the same time. Since then we have built and flown 12 sailplanes, of which 10 have been tailless. In fact, we decided some time ago to build no more tailed sailplanes for ourselves. Our dedication to this ideal caused Bob Dodgson some consternation a couple of years back, when we won a "Windsong" kit at a contest. His fears increased noticeably when we confided to him we felt an inverted Eppler 214 to be an acceptable airfoil for a "plank" design.

We must confess to all (1) we are now building the "Windsong" kit, (2) it will have a tail, and (3) it belongs to our son. However, we do have two 'wings currently under construction: a 1/4 scale Marske Pioneer II-D (which will be flying at the Richland Fun Fly in May), and a large swept 'wing for unlimited class competition. Plus, there are construction plans for at least two more tailless designs either already drawn up or rolling around inside our heads.

We are genuinely excited to see a surging interest in flying wings and tailless designs, and believe this is probably due to an increase in slope soaring activity. The explanation for this correlation has to do with the characteristics of nearly all of the currently available tailless designs, be they kits, magazine offerings, or scratch-built creations. Tailless soarers are in general conveniently compact, they tend to fly faster than conventional designs of the same wing loading, and they usually show good aerobatic capability. Since their relatively high sink rate is not the disadvantage on the slope that it is in thermal flying, these 'wings, with all of their positive qualities, are a dream come true for the dedicated slope soarer.

More and more thermal flyers are being attracted to tailless sailplanes as new designs demonstrate lower sink rates, and it appears further increases in performance are probably not very difficult to obtain. The fact is, there are certain AMA events in which tailless designs are specifically excluded due to the overwhelming advantage they've demonstrated in the past. We believe flying wings can be competitive in both thermal duration and F3B contests.

At the flying field, we and our 'wings have always been met with numerous questions, and the fact many people are naturally curious about tailless aircraft has been readily apparent to us from the start. There is a hesitancy on the part of most modelers, however, when it comes to actually building a tailless design, and we think this is due to insufficient available information. What we would like to do is share some of the information which we have been (and still are) accumulating, perhaps alleviating some of the perceived information gap, and maybe giving some readers the courage to build and fly a tailless sailplane. We would welcome the opportunity to write about the new airfoils specially designed for tailless aircraft, construction techniques which can better assure rigid structures, methods of improving performance, some thoughts we have about a flying wing perhaps being the best Cross Country (XC) machine as well as the best RC-Hand Launched Glider (RC-HLG), and other assorted topics.

As you can probably tell, we have strong feelings about the importance of sharing information; equally important in our minds is saying <u>where</u> the information was found. Revealing an information source has several beneficial effects: (1) it gives credit where credit is due, (2) it lends credibility to the statements offered, and (3) it gives the interested reader an opportunity to explore a little further.

We are eager for feedback on the ideas presented here, and always appreciate comments, questions and information about flying wings and tailless aircraft of any type.

## GOLIATH

(This was originally composed as a part of a letter to Jim Gray, then Editor of RC Soaring Digest. It appeared in RCSD as an article.)

We know you're interested in flying wings, and thought perhaps you would be interested in a recent experience of ours.

Dave Jones' Blackbird 2m has held a special fascination for us for quite some time. We have previously built it with only one exception to the plans; we tapered the main spar. Being the sorts of people who do a lot of reading, however, we decided the basic design had some other possibilities. What came from this was an FAI maximum wing area (2325 square inches), nine pound plus flying wing!

Our original intent was to construct a XC machine which would be visible at high altitude, be immune (by definition) to horizontal stabilizer blowoff at high speed, and be just as maneuverable as a "standard class" model. We used the CJ-$25_2$09 airfoil.

The first "flights" consisted of some hand launches (!) at a Portland Area Sailplane Society XC meet. Due to being tail heavy, this amounted to controlled crashes, however. Our next attempts, with more weight in the nose, took place at a local slope site. SUCCESS!

We had a highly modified Metrick (Selig 3002 airfoil on straight foam core wings, R E A F) and our Blackbird 2m with us. The wind was blowing pretty good, but from an angle, so the planes flew "upwind" and "downwind". You could really get some ground speed going one way, but had to fight your way back going the other. The Blackbird flies very well in thermals, but it's a real joy to fly on the slope, and the Metrick flies MUCH better on the slope than our previous modified kit. The enlarged Blackbird, however, was AWESOME!

Thrown over the edge, it immediately started climbing - much faster climb than either of the other two ships. In just a few seconds it was higher than either of the other two ships had gotten in nearly two hours of flying.

Previous experience with the 2 meter version really cut down the learning time, and within a few laps it was really performing. Here was an airplane with a span of nearly 9 feet, whipping up and down the face of the slope like there was no diagonal vector to the wind at all. Some down trim and the speeds were phenomenal; we made some very close passes and there were no shrieks, no whistles, not even a whisper. If there was any noise at all, and there was some controversy, it could only be described as a soft hum. Beautiful, graceful loops. The turns were unbelievable - 75 to 80 degree bank, some up elevator, and the inner wingtip was close to being the pivot point. In nature films you often see flights of birds in which the birds flip directions. The only difference here was the absolute smoothness with which this airplane moved. If ever the term "like it was on rails" applied, it was here.

One of the difficulties we have is at times our piloting skills do not quite meet the challenges of situations we run into. Such was the case here. We lost sight of her below the edge of the cliff and lost control. Next thing we knew there was nothing but the shattered hulk in the water below.

It seems like when we finish building an airplane we always say to ourselves, "If we ever build this thing again, we're going to ...", and so it is with this one, too. We'd be happier with thicker sheeting over the leading edge, and a lighter fin structure, and both of these changes will be incorporated into the new one.

We're making rapid progress on the replacement. A couple of nights ago we spent some time watching the computer draw out the 26 new wing ribs, and we then cut them out. Tonight we used the table saw to cut the tapered spars.

Still, the emotional high we experienced during that 20 minute flight of the original will never be forgotten. What an experience it was!

Goliath's replacement - Pirouette

## PIONEER II-D

(This was originally written as a part of a letter to Jim Gray, then Editor of RC Soaring Digest. It appeared in RCSD as an article.)

We flew our 1/4 scale Pioneer II-D in Richland Washington over the weekend and thought we'd drop a note to you letting you know of our success.

This was really an "un"contest - a fun fly. In fact, it was advertised as the "1988 National Mid-Columbia RC Soaring Scale Fun Fly and Soaring Social." It took place over three days, the 27th, 28th and 29th of May. The site was probably one of the best slope soaring sites in the United States, a hill with a face of about 40°, a height of several hundred feet and a length of over a mile.

It rained Saturday, but Friday and Sunday were great days for flying the ridge lift, with a wind speed of about 25mph across the lip of the ridge both of those days. The air was fairly turbulent against the hill, but even 50 feet out the air was very smooth with tremendous lift at all times. When the wind slowed down at all it was because of the large amount of air backfilling a thermal. Visibility from this site is 30 miles to the horizon, and three major thermal streets were visible at all times on Friday. The wind blew steady all day Sunday.

Sixty plus fliers had entered over 100 sailplane and "power scale" (F-16, P-51, F-111, Mirage, "Dago Red", etc.) models. Most of the sailplanes were constructed from kits produced in Germany - fuselage of fiberglass, wings of foam with a covering of balsa, obechi, plywood or fiberglass. Models included ASKs, a Twin Acro, DG-400, Sisu, Discus, Schweitzer 1-26, etc. The power scale ships were primarily of foam, with a fiberglass and epoxy covering. Erich Eike, of Canada, had a beautiful German primary glider, complete with pilot, and covered with an antique white fabric, and a Reiher. The primary and our Pioneer II-D were just about the only rib and fabric structures at the meet, and the only ones to fly.

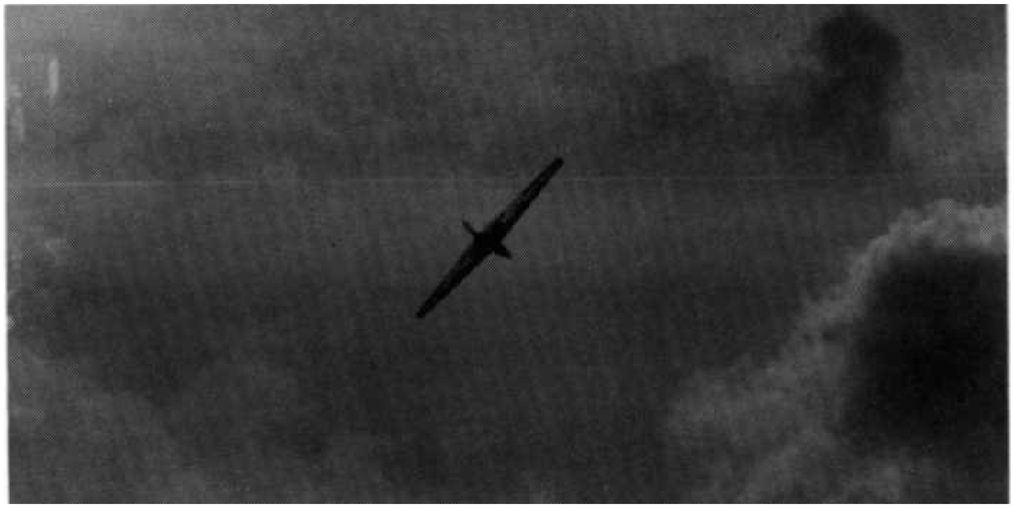
Our Pioneer II-D was flown in the "blueprint" configuration, without the modifications of John Irwin's N86TX (which will be added as soon as possible). We tried to get acrylic to conform to our canopy mold, but without success, so $13 in materials later we decided to cover the mold in plastic wrap and just get the shape in fiberglass and epoxy. Several people with molding experience talked to us at the meet and we'll soon have a clear canopy so our future instrument panel and pilot show. We had the fiberglass seat done already, and it was a simple matter to wrap the receiver in foam and seat belt it in place with a strip of velcro.

On the Wednesday before the meet we finally had some decent weather here in western Washington and we took her out for a test glide at the Little League field. With just a bit more weight in the nose she was flying fast and straight from a hand launch.

In Richland on Friday we were a pretty anxious pair. Wind at 22 to 28 mph, first soaring flight, etc., etc. Since we had built the whole airplane together, Bill's half was forced to follow Bunny's half when she decided to fly it. We straightened out a few minor problems and were ready. Many people had inquired as to whether a "real" Pioneer II-D actually exists, if our model was an assembled kit, if it had flown before, and just how scale it really was. We were able to tell them about N86TX which was (hopefully) being flown this same weekend, that our model is certainly was not a kit, that we had three hand launched glides on her (only the last being a true success), and that it was indeed scale, airfoil and all. Bunny had constructed the rudder single handed and it's a work of art which a lot of people appreciated - the 1/64" plywood gusseting and 1/32" plywood cap strips can be seen through our still clear covering.

Mike Bamberg, a member of the Portland (Oregon) Area Sailplane Society was drafted into launching her in front of an audience of about 100. Probably half felt she wouldn't fly at all, predicting she would just tumble through the air into the gravel "like all flying wings"; the other half were hoping we had done everything right and she would fly at least well enough to land again in one piece. Mike aimed her down at about a 20° angle, an effective angle of attack of zero, and pushed her gently into the air. She continued down for a few feet and then rotated into a beautiful climb - a maneuver which was met with a genuine cheer from <u>everyone</u> in the crowd.

Mike's a good coach, and he soon had us exploring the flight envelope with gentle turns, attempted stalls, tight turns with full up elevator and later with crossed controls. We tried the airbrakes, too. She simply dropped her nose and slowed down, maintaining altitude. Mike flew her for a while, of course, and he remarked she was a very smooth flying machine. He did a couple of big graceful loops and a nice gentle roll, too!

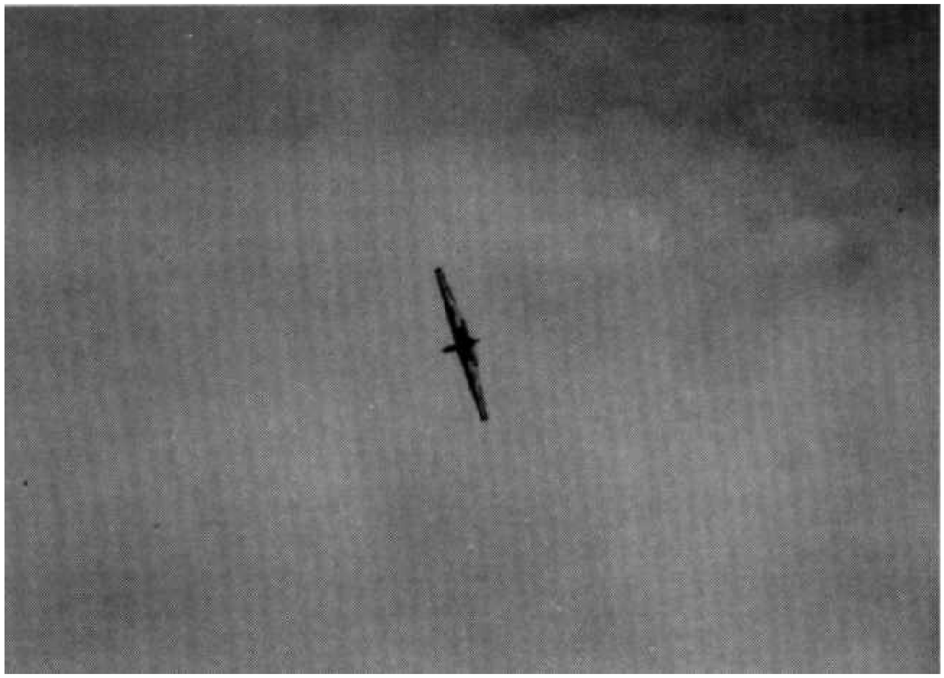


This site has a gentle roll at the top with a slightly angled grassy landing area behind. There is no rotor and just a bit of turbulence during the last few feet before touching down. Use of the airbrakes was not necessary as her flying speed was just a bit faster than the wind velocity over the crest of the hill, and she settled right in with no problem.

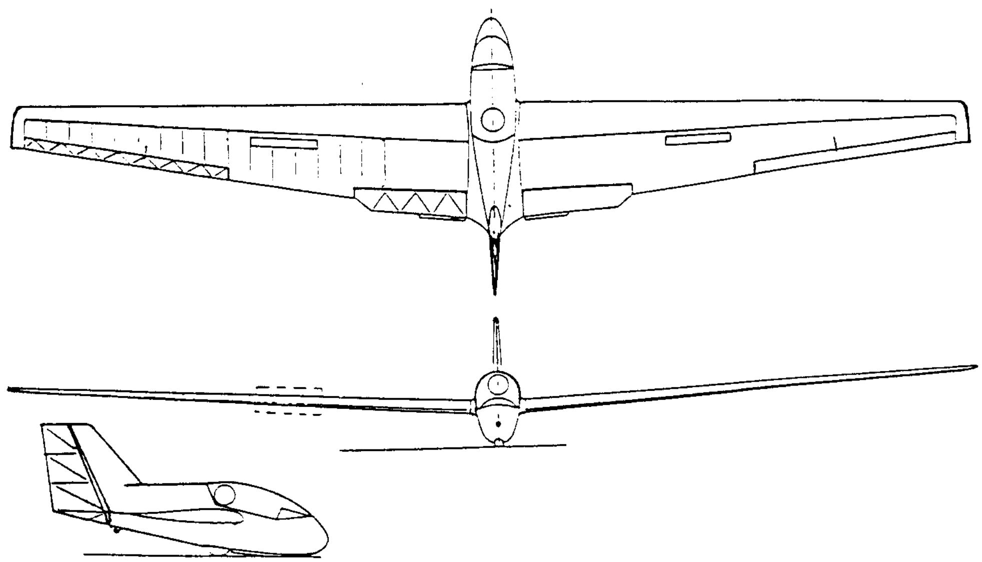
The second flight on Friday was relatively anticlimactic following that initial performance, but more and more people came over for a closer look after each of the two flights. Now they asked about fuselage molds, airfoil templates, and construction plans. It was amazing.

Our third flight was on Sunday afternoon. Many people had arrived on Saturday and so had not seen the Pioneer fly previously. We were again inundated with questions both before and after our flight.

Our Pioneer flies just like it's full size. Turns can be made flat and gentle, or can be very steep and tight. Use of up elevator in a banked turn not only makes it tighter but the airplane accelerates noticeably. The nose doesn't drop below the horizon in a stall, it just comes down a bit and the airplane immediately starts flying faster. Full up elevator in a combination of slope and



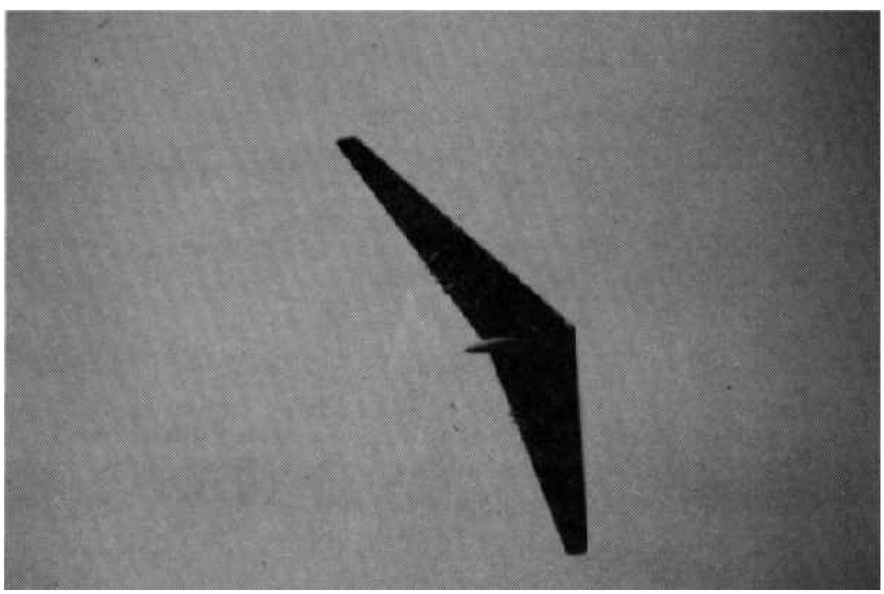
thermal lift makes for an interesting experience. The nose goes up to about 20° and she lifts straight up. After a while the nose comes down, but if you're still holding full back it just rises again and the whole airplane goes straight up again. We climbed over 800 feet in four "steps" this way and stopped only because the thermal we were in got stronger with each step and we were unsure of getting her down if the thermal became more intense. With just a small amount of down elevator she can move extremely fast.



| | |
|---|---|
| WINGSPAN .......... | 42.6 ft |
| ASPECT RATIO ....... | 12.6 |
| WING AREA ......... | 144 sq ft |
| PAYLOAD ........... | 240 lbs |
| EMPTY WEIGHT ....... | 350 lbs |
| GROSS WEIGHT ....... | 630 lbs |
| WING LOADING ....... | 4.4 psf |

L/D max .......35 @ 60mph
MIN SINK ......2.3fps @ 45mph
2 mps SINK @ .. 97 mph

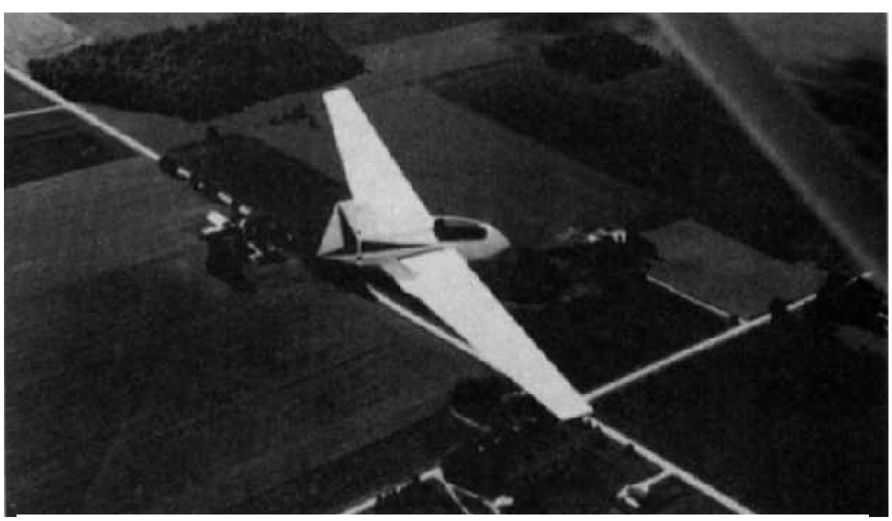
There were three flying wings at the meet - our Pioneer II-D, a foam and fiberglass (sort of a) Horten IX of 12 foot span, and a true to scale 14 foot span Northrop YB-49, constructed of foam and fiberglass with fences and fins of lite-ply. It used the same airfoils as the original (NACA $65_1$3-019 and $65_1$3-018), and the same wing twist ($4^{\circ}$), but the only controls were elevons - no flaps or drag rudders. The Horten was launched twice and just did not do well at all; a controlled crash and a noncontrolled crash, probably due to a combination of interference, being tail heavy, and suffering from tip stall. The YB-49 had an abortive first flight due to being launched straight out. It stalled and fell, suffering some minor damage. The launch for the second attempt was great (three people and the nose down). It rotated just like the Pioneer and was off. It looked to be flying at about scale speed, but there were a couple of <u>really</u> close passes for the cameras which were unbelievably fast. The turns were graceful and wide, and the whole flight could have been scenes from a late fifties sci-fi flick. This airplane flew just once, but definitely "stole the show".



One thing which impressed us was that the failure of the Horten was nearly disregarded, and the flight of the YB-49 and the three flights of our Pioneer II-D turned a lot of people on to flying wings! They were at first curious, then intrigued, and then genuinely interested. We saw a number of people there become converts. In three flights our Pioneer was flown by both of us, Mike Bamburg, Alan Halleck (the builder of the Horten), and Wil Byers (contest director). Wil has extensive slope experience, he lives just a couple miles from this site, but he had never flown a 'wing before! He said, "This things flies like it has a tail! It's really smooth. This is great!" Alan has designed and flown several flying wings for aerobatics and racing; he commented on how well she flew also. We're wondering how the flight characteristics will improve once all of the hinge gaps are sealed. We've got releasable tow hooks mounted under the wings, so our next flights may be off the winch.

It is unfortunate you couldn't be there in person, as the entire weekend was a great experience. By unanimous vote of those in attendance, there will be a repeat next year over the same weekend. Perhaps you will have better luck in attending next year's event.

(Yes, Jim did make it to the event in 1989!)



J.P Chevalier's full sized Pioneer II in flight.

## AKAFLIEG BRAUNSCHWEIG'S SB-13

Are you looking for a flying wing or tailless design for a scale project? Take a look at the first flying wing constructed with composite material technology! The SB-13 was designed to be a 15 meter high performance Standard Class sailplane. Without flaps to achieve variable camber, flight performance was to be achieved by elimination of fuselage and stabilizer drag. Constructed by Akaflieg Braunschweig in Germany, the SB-13 was successfully flown twice from aerotow on 18 March, 1988.

The first design, with straight leading edge, was modeled at 1/3 scale and flown using radio control, but the model revealed spar flutter at a scale speed of 120 km/h (75 mph). The sweep was taken out of the spar and wing at the root to reduce the bending load and carbon fibers were added to the spar layup to increase stiffness. These modifications raised the flutter speed to 270 km/h (over 165 mph). Manufacturing the curved spars posed its own difficulties, but these were all solved quite nicely; a static bending load test that was to go to the destruction of the spar was terminated when the spar survived a load 2.3 times greater than the design maximum!

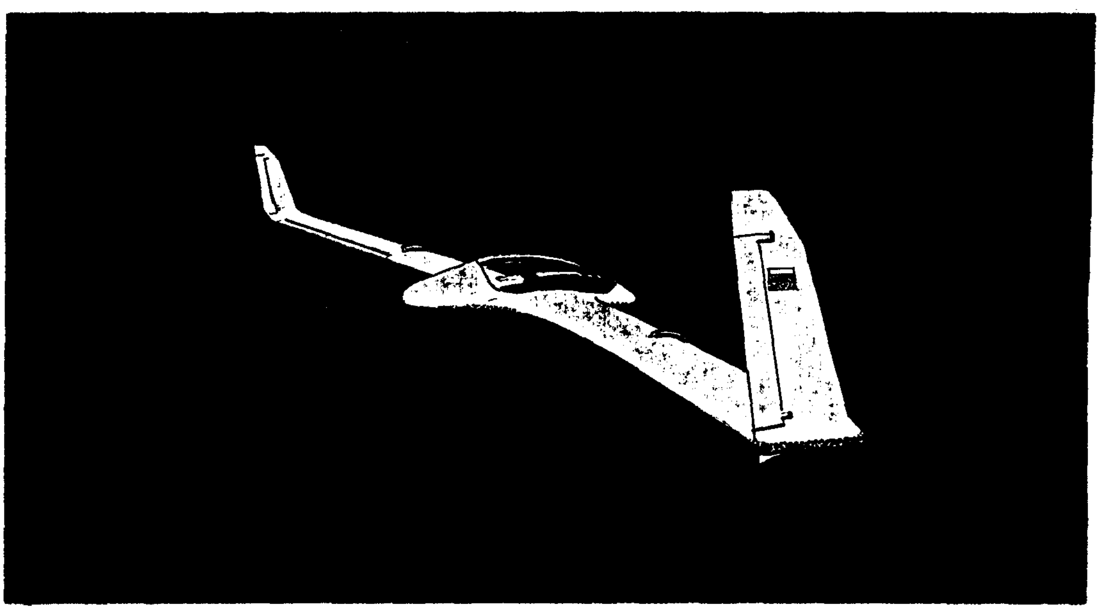
The airfoils used were designed for zero moment coefficient and maximum laminar flow. The resulting sections, HQ 34N/14.83 at the root and HQ 36N/15.12 at the tip, are laminar to 89% chord on the upper surface. Wing twist is but $1.5^o$, dihedral is $4^o$, the aspect ratio is 19.4, overall wing sweep is $13.5^o$. The elevators are near the wing tips, with the ailerons inboard; both have their own special airfoil. The spoilers are the height of the wing section and are mounted on vertical tracks, coming out of the upper surface only. When turning, the inner rudder deflects $70^o$ and the outer deflects $15^o$. The winglets use the FX-71-L150/30 section, and are rather interesting as they appear to have the Schuemann tips that are becoming so popular.

The SB-13 has a tandem landing gear setup with both wheels retractable. The fuselage is of glass fiber and includes a special safety system consisting of three parachutes which can bring aircraft and pilot down together in case of mishap. The parachutes are vacuum packed, weigh a total of 20 kg (44 lbs.) and take up only 40 liters volume (about the size of a ten gallon aquarium).

Performance is quite excellent: minimum speed is 70 km/h (under 45 mph), maximum is 210 km/h (130 mph), and the sink rate is a very low .53 m/s (1.74 ft/sec) for a glide ratio of about 43.5 to 1!

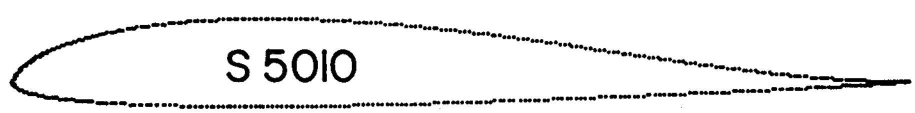
All of the above information was found in TWITT newsletters (4, 10, 21, and 23). TWITT (The Wing Is The Thing) is a group of flying wing enthusiasts who promote the design and construction of tailless and all-wing aircraft. One of their goals is to construct their own full size high-performance tailless sailplane.

Should you decide to model the SB-13, we have plans which are a bit more detailed than those included here. Although most photos make it appear the wing is a smooth arc, it is actually constructed with a series of straight segments. Construction of a foam core wing, therefore, may be a bit time consuming but is certainly possible.

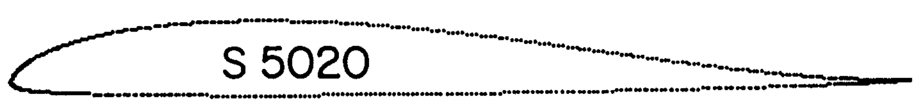


## SELIG S5010-098-86
## SELIG S5020-084-86

These two airfoils were published in SOARTECH #7, "The FLYING WING Edition". As you can tell by the "S" prefix, they are from the computer of Mike Selig. Dave Jones (England) had asked Mike to design some sections for tailless planforms, the resulting sections would then be placed in SOARTECH. Mike came through with these two profiles. They both have positive pitching moments and could be used for "plank" designs. The moments are not so strongly positive as the Eppler 184 and 186, 228 and 230. However, these sections should be able to give better performance than the Epplers due to decreased drag and higher maximum coefficient of lift.




The S5010-098-86 is 9.8% thick. It has a moment coefficient of +0.0086 and a zero lift angle of +0.64 degrees.




The S5020-084-86 is 8.4% thick. It has a moment coefficient of +0.0084 and a zero lift angle of +0.82 degrees.

If you decide to use these sections, there are a couple of things to remember:

First, the leading edge of both sections is relatively blunt. According to Dave Jones' (California) experience, this is probably detrimental to penetration if you're operating with a light wing loading.

Second, the trailing edge of both sections is relatively thin. If you're building an all wood structure this leads to difficulties in construction. Taken together, these two items point in the direction of a foam core structure.

Another thing to keep in mind is the noticeable performance increase to be derived from having the trailing edge of the wing straight and sharp. A blunted trailing edge does terrible things to the pressure gradients over the aft portion of the wing and can disrupt the airflow well forward. The modern computer generated sections we're seeing these days seem to thrive on sharp trailing edges, and these two Selig sections are no exception.

Many of us are still living in the dark ages; we take a piece of trailing edge stock and glue it into place, then we take the covering material and attach it directly to the trailing edge stock after a minimum of sanding. Such procedures may be OK for powered craft, but we're looking for peak performance from our sailplanes.

Laminating the trailing edge from two pieces of 1/16th sheet with 1/64th plywood between is a superior method, from both a structural and performance view. The balsa sheets should be carefuly mated to the plywood at the trailing edge to preserve the airfoil section, and if you can manage a knife-sharp edge on the plywood, so much the better. You might also consider cutting your foam cores to accept 1/64th plywood or fiberglass skins; these techniques make sharp trailing edges even easier to obtain. Take some time getting the trailing edge perfect - it's worth the effort!

These two sections look VERY promising. If any readers put them to use we'd appreciate hearing about their performance.

S5010

| X | Y |
|---|---|
| 100.000 | 0.000 |
| 99.676 | 0.001 |
| 98.707 | 0.007 |
| 97.101 | 0.036 |
| 94.870 | 0.108 |
| 92.041 | 0.256 |
| 88.667 | 0.516 |
| 84.828 | 0.903 |
| 80.608 | 1.406 |
| 76.076 | 2.008 |
| 71.307 | 2.688 |
| 66.377 | 3.420 |
| 61.355 | 4.163 |
| 56.296 | 4.877 |
| 51.247 | 5.529 |
| 46.251 | 6.093 |
| 41.348 | 6.546 |
| 36.576 | 6.873 |
| 31.969 | 7.063 |
| 27.560 | 7.113 |
| 23.383 | 7.023 |
| 19.473 | 6.799 |
| 15.860 | 6.445 |
| 12.573 | 5.968 |
| 9.637 | 5.377 |
| 7.071 | 4.688 |
| 4.889 | 3.915 |
| 3.102 | 3.081 |
| 1.718 | 2.214 |
| 0.739 | 1.348 |
| 0.167 | 0.533 |
| 0.015 | -0.140 |
| 0.424 | -0.650 |
| 1.456 | -1.084 |
| 3.028 | -1.471 |
| 5.123 | -1.804 |
| 7.718 | -2.082 |
| 10.785 | -2.306 |
| 14.291 | -2.481 |
| 18.194 | -2.609 |
| 22.448 | -2.688 |
| 27.008 | -2.715 |
| 31.829 | -2.691 |
| 36.864 | -2.623 |
| 42.055 | -2.517 |
| 47.345 | -2.381 |
| 52.675 | -2.219 |
| 57.983 | -2.039 |
| 63.209 | -1.846 |
| 68.292 | -1.645 |
| 73.173 | -1.443 |
| 77.792 | -1.243 |
| 82.095 | -1.049 |
| 86.030 | -0.863 |
| 89.547 | -0.691 |
| 92.603 | -0.527 |
| 95.163 | -0.367 |
| 97.211 | -0.212 |
| 98.730 | -0.088 |
| 99.678 | -0.019 |
| 100.000 | 0.000 |

S5020

| X | Y |
|---|---|
| 100.000 | 0.000 |
| 99.683 | -0.001 |
| 98.736 | 0.000 |
| 97.160 | 0.015 |
| 94.964 | 0.066 |
| 92.171 | 0.186 |
| 88.833 | 0.413 |
| 85.028 | 0.766 |
| 80.840 | 1.234 |
| 76.339 | 1.793 |
| 71.594 | 2.430 |
| 66.672 | 3.116 |
| 61.644 | 3.827 |
| 56.576 | 4.524 |
| 51.519 | 5.170 |
| 46.516 | 5.736 |
| 41.608 | 6.198 |
| 36.830 | 6.539 |
| 32.218 | 6.748 |
| 27.803 | 6.821 |
| 23.620 | 6.759 |
| 19.702 | 6.565 |
| 16.081 | 6.244 |
| 12.785 | 5.802 |
| 9.837 | 5.249 |
| 7.257 | 4.596 |
| 5.059 | 3.862 |
| 3.252 | 3.065 |
| 1.843 | 2.234 |
| 0.833 | 1.401 |
| 0.219 | 0.613 |
| 0.002 | -0.049 |
| 0.308 | -0.507 |
| 1.226 | -0.815 |
| 2.727 | -1.037 |
| 4.807 | -1.192 |
| 7.434 | -1.310 |
| 10.563 | -1.404 |
| 14.148 | -1.478 |
| 18.141 | -1.534 |
| 22.491 | -1.569 |
| 27.150 | -1.583 |
| 32.064 | -1.576 |
| 37.179 | -1.550 |
| 42.436 | -1.507 |
| 47.776 | -1.449 |
| 53.139 | -1.379 |
| 58.462 | -1.297 |
| 63.687 | -1.206 |
| 68.753 | -1.108 |
| 73.601 | -1.004 |
| 78.178 | -0.896 |
| 82.430 | -0.785 |
| 86.308 | -0.672 |
| 89.767 | -0.557 |
| 92.767 | -0.440 |
| 95.276 | -0.317 |
| 97.297 | -0.188 |
| 98.763 | -0.079 |
| 99.686 | -0.018 |
| 100.000 | 0.000 |

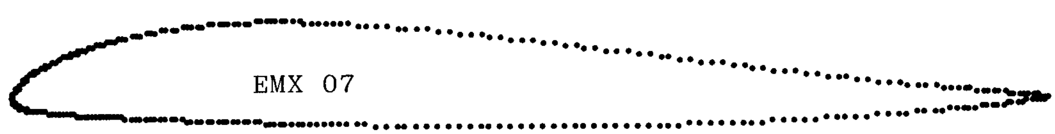
# "DELTA" SECTIONS:

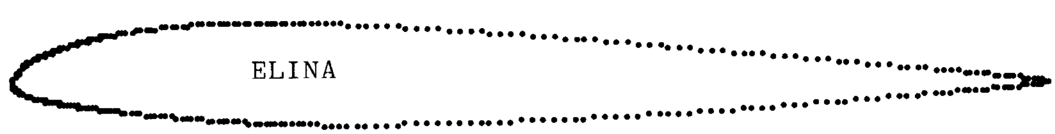
## EMX 07, ELINA, AND PHOENIX

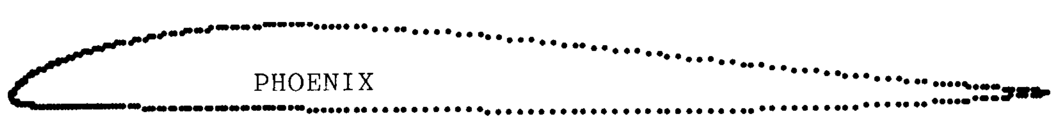
Some new flying wing airfoils this time! These come courtesy of DELTA, magazine of FSV Versmold, a club in Germany devoted solely to tailless sailplanes. These sections appeared in issue #6 and all three were designed by Dr. Martin Lichte of VFW Fokker, a German aerospace company. Dr. Lichte is also the author of a book entitled "Nurflugelmodelle, Grundlagen fur Entwicklung und Einsatz" ("Only-wing-models, Foundations for Development and Use"), published by Verlag fur Technik und Handwerk GmbH in Germany.

The EMX 07 and ELINA sections require wings with aspect ratios of 10 or more and sweepback of $10^o$. Set up this way neither will require geometrical twist. A wing loading of 9.5 to 13.5 $oz/ft^2$ is recommended. The EMX 07 is a good profile to use for thermal flying and has a low sink rate. The ELINA is simply "a hellishly fast" section, probably best suited to the slope. The PHOENIX airfoil is for lightly loaded (under 7.5 $oz./ft^2$) 'wings designed as floaters. For the PHOENIX section, $10^o$ of sweep should again be used, along with about $3^o$ of geometrical twist. (With sweepback the tips should be at a lower angle of attack than the root.) The L/D of this airfoil should be excellent.

| | EMX 07 | | ELINA | | PHOENIX | |
|---|---|---|---|---|---|---|
| X | Yu | Yl | Yu | Yl | Yu | Yl |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.25 | 1.82 | -0.87 | 1.75 | -0.94 | 1.60 | -0.60 |
| 2.50 | 2.73 | -1.12 | 2.53 | -1.32 | 2.41 | -0.71 |
| 5.00 | 3.99 | -1.43 | 3.58 | -1.84 | 3.57 | -0.83 |
| 7.50 | 4.94 | -1.62 | 4.33 | -2.24 | 4.43 | -0.88 |
| 10.00 | 5.67 | -1.77 | 4.86 | -2.58 | 5.10 | -0.92 |
| 15.00 | 6.71 | -2.01 | 5.56 | -3.16 | 6.08 | -1.01 |
| 20.00 | 7.24 | -2.21 | 5.87 | -3.59 | 6.62 | -1.10 |
| 25.00 | 7.45 | -2.39 | 5.94 | -3.90 | 6.87 | -1.19 |
| 30.00 | 7.34 | -2.54 | 5.82 | -4.07 | 6.83 | -1.28 |
| 40.00 | 6.60 | -2.75 | 5.30 | -4.04 | 6.21 | -1.45 |
| 50.00 | 5.47 | -2.82 | 4.55 | -3.74 | 5.21 | -1.60 |
| 60.00 | 4.20 | -2.76 | 3.72 | -3.25 | 4.06 | -1.66 |
| 70.00 | 2.94 | -2.52 | 2.83 | -2.62 | 2.87 | -1.58 |
| 80.00 | 1.78 | -1.97 | 1.92 | -1.84 | 1.76 | -1.33 |
| 90.00 | 0.83 | -1.26 | 1.06 | -1.04 | 0.78 | -0.89 |
| 95.00 | 0.45 | -0.76 | 0.61 | -0.61 | 0.42 | -0.49 |
| 100.00 | 0.15 | -0.15 | 0.14 | -0.14 | 0.09 | -0.09 |



# TAILLESS FOR RC-HLG

Those who have seen the Proceedings of the M.A.R.C.S. National Sailplane Symposiums recognize the wealth of information contained therein. We have read our copies several times, but it seems each reading finds us discovering some new piece of information we have apparently missed previously. Too, we are often given to assembling facts and ideas from several of the Proceedings and coming up with a synthesis which we then are able to put to use in some way.

The Proceedings for 1983 and 1984 included some good information on Hand Launch Sailplanes (Class A). We had been thinking about building a Hand Launch Sailplane without a conventional tail assembly because of our intrigue with tailless aircraft, but it occurred to us while reading the Proceedings that each of the difficulties and/or problems outlined could be solved by going to a tailless design. Here are some of the major points:

(1) The performance of an RC Hand Launch Sailplane seems to be inversely related to its wing loading, i.e.; the lower the wing loading, the better the performance. In constructing our HL, we used a full D tube of 1/16" balsa and 1/8" spruce spars. Ready to fly, it weighs 16 oz. But the wing loading, 3.5 oz./ft$^2$, is actually below the FAI minimum of 3.95 oz./ft$^2$, so making the structure any lighter is really quite pointless. She is very strong structurally and has cartwheeled countless times with no damage. We finally broke the fin by running into a cyclone fence. Our experience points to the ease with which a low wing loading can be obtained.

(2) Keeping the Reynolds number above 60,000 is very important. Going below that magic number makes it very difficult to control airflow over the upper surface of the wing, and small gusts can stall a wing easily. A low Reynolds number also makes pilot control a critical factor. Our RC-HLG has a tip chord of over 9 inches and flies faster than a conventional design, so its Reynolds number is always well above the minimum value.

(3) A conventional RC-HLG with a constant chord or tapered chord wing is very sensitive to CG placement - even 1/16" may make a difference - and a lot of trimming seems to be the rule. On our 'wing it was very easy to find the correct CG: we used a rough approximation at first and then added and subtracted weight until she flew well with the elevons trailing smoothly with the rest of the wing. No worries of looping on launch because of wrong incidence angle, either.

(4) Thermals that are low to the ground tend to be very small, so a tight turning radius is necessary to take advantage of them. Our tailless RC-HLG turns very tightly.

(5) Reduction of drag is of paramount importance for these small airplanes: antennas are notorious drag producers when left out in the airstream, and any protruberance has a negative effect on performance. We were able to run our antenna completely inside one wing, and reduced drag further by eliminating the rear fuselage and entire tail assembly. The reflexed airfoil has been accused of high drag, but this disadvantage may be at least partially overcome by the higher Reynolds number of our 'ship in comparison to conventional sailplanes with smaller wing chords and lower velocities.

(6) When one of these little airplanes hooks up with a thermal it tends to get out of sight quickly. While some flyers rely on color schemes to enhance visibility, perhaps the best method is to simply increase the area of the wing. Our tailless RC-HLG has over 700 $in^2$ of area all in one spot. It's aspect ratio is about 5:1.

For those of you curious about what our RC-HLG looks like, it's simply Dave Jones' "Blackbird 2m" reduced to exactly 75%. We are very pleased with its performance, and are always trying to get it captured by a killer thermal at the local Little League field. (Next stop - the slope!) It hasn't won any contests, but then we haven't entered it in any, so we don't feel bad. For those of you who do enter RC-HLG contests, we hope we've given you some ideas for your next design.

# TAILLESS FOR CROSS COUNTRY (XC)

Last year at about this time we heard about a XC meet in Portland Oregon and decided to go. We didn't enter, but we did take an airplane with us - an FAI maximum area tailless. It wasn't trimmed for flight; in fact, it hadn't been flown at all, having been completed the night before. With the help of several people at the contest (lead weights from Jim Arnold and some great hand launches of our 10 pound monster by Mike Bamberg...) we found that while there was certainly some potential, being severely tail heavy is no way to try to fly a 'ship of this type. We were most grateful for the impressions of others at the contest (particularly Alan Halleck, who got us even more excited about the its potential than we were already). We had such a fun time even without competing, we're planning on going back again this year.

We had the chance a few weeks later to add more weight in the nose and try her out as a cliff soarer. She flew magnificently until pilot error put her in the water. We were certainly heartbroken over a totally destroyed airplane with only 20 minutes of flight time, but we were ecstatic over her performance and determined to build a replacement. The replacement, Pirouette, is now finished and has flown successfully from winch launches.

Why would anyone build an FAI maximum area tailless design? Well, there is a certain morale boost to be gotten from having the biggest airplane at a contest... particularly when it has no tail. Seriously, there are some logical reasons, and we'll outline the major points here:

First, as a general rule, "bigger flies better", and we certainly found this rule to be true while flying our giant.

Second, there is an upper weight limit of 5 kg. (11 pounds) for FAI sailplanes. The weight limit is reached very fast when building a big conventional sailplane.

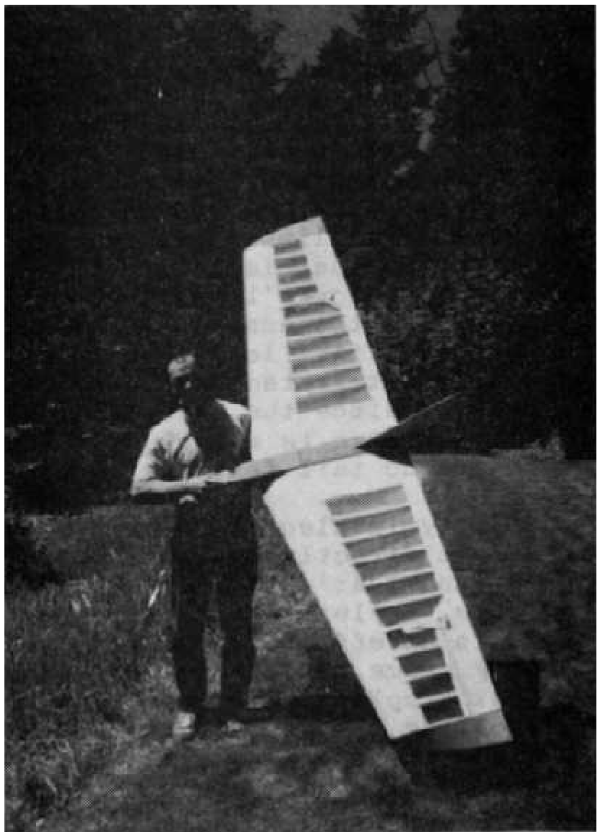
Third, keep in mind the wings of a conventional sailplane must support all of the aircraft's weight, and all of the flight stresses. The stresses on a XC machine can be extremely high while speeding between thermals and traveling through "microbursts" of turbulence, and it is little wonder the casualty rate for these machines is relatively high. The ultimate effect of the FAI weight limit is to prevent really large conventional sailplanes from having the strength they need.

Tailless designs have an inherently light structure. In fact, it is sometimes difficult to end up with a completed aircraft which meets the minimum wing loading requirements of 4 oz/ft$^2$, as we found out with our HL 'wing. Most tailless designs are able to take advantage of what is called "span loading." This is a topic we'll talk about in another article, but the concept translates into more manageable flight loads and an airframe which is easily integrated into a very strong structure. Since the stabilizer of aany tailless design is a part of the wing itself, there are no tail feathers to blow off.

Visibility is also of concern when flying XC, as height directly equates to distance and speed, and that's the combination which wins contests. While many color schemes have been tried in an effort to maximize visibility, nothing seems to work so well as having the largest airplane possible. We feel controlling the distribution of surface area can also assist, as a large square is easier to see at altitude than a thin rectangle of the same area.

Our XC machine relies on Dave Jones' "Blackbird 2m" design (the same basis as our RC-HLG). By multiplying all linear dimensions of the 2 meter original by 1.36 we arrived at a wingspan of about 107 inches, a root chord of nearly 27 inches, and a tip chord of over 17 inches. The overall weight of Pirouette is about 10 pounds, and her wing area is just under the FAI maximum of 2325 in$^2$. This still makes for "interesting" hand launches, and our 12 volt winch groans if there is a breeze. She turns on a dime and gives change. Her top speed is deceiving because of her size, but it is at least half again as fast as an equivalently loaded conventional design!

Between now and this year's Portland XC meet we'll be practicing as frequently as possible. See you there!



# COMPUTER PROGRAMS FOR DETERMINING SWEEP AND TWIST

There are three general types of tailless sailplane:

(1) the "plank," usually with leading and trailing edges parallel, or nearly so, and a central vertical fin,

(2) the swept wing, with either a single fin centrally located on a boom or one fin at the end of each wing, and

(3) the true "flying wing" which is a swept wing with no vertical surface at all.

We've been flying planks for several years, and most people are shocked to find there is no twist in the wings to provide stability. The airfoils used on planks are self stabilizing and accomplish this through a reflexed trailing edge. Simply put, the CG is located more forward than on a conventional design, and the upturned trailing edge applies the down force normally exerted by the horizontal stabilizer. The plank, then, is nothing more than a conventional sailplane with the stabilizer built into the wing itself rather than hanging on a boom. Dave Jones' "Raven" design, which we've been flying, will actually be DEstabilized if twist is incorporated into the wing.

Swept wing tailless and true flying wings, however, use twist to achieve stability. Sometimes this is accomplished with an actual physical twist being built into the structure. Other times, if the airfoils are chosen carefully, the twist can be accomplished aerodynamically, and the wing built with no geometric twist at all.

The amount of twist required is based on four things:

(1) the moment coefficients of the root and tip airfoils,

(2) the zero lift angles of the two sections,

(3) the degree of sweep, and

(4) the amount of stability desired.

The obvious question is, "If I know these four things, can I calculate the geometric twist required for my design?" As a matter of fact, yes, you can. You can even do something a little different, too. If you know how much geometric twist you want to use, you can calculate how much sweep your design will need! How about that!

The formulae for these routines were found in two different places: in an article entitled "Pfeilung - ja - aber wie gross" ("Arrowshape - yes - but how large") by the late Werner Thies and published in Flug + modelltechnik (FMT) in the February, 1984, issue, and in the book "Nurflugelmodelle," authored by Martin Lichte. The equations are different in appearance but are mathematically equivalent. The routines printed here are derived from the FMT article and assume swept wings with no taper and either foam core wings or stack sanded ribs for construction.

There are a few generalizations that may help you better understand the routines.

(1) An undercambered root section will need more wing twist than a semisymmetrical root section when using the same tip section,

(2) the higher the sweep ratio the less twist is required,

(3) more twist equates with greater stability because the CG must be moved forward to trim, and

(4) the twist itself can come from either geometric twist (physical warping) or aerodynamic twist (difference in zero lift angles of the sections).

Two terms need further explanation. The sweep ratio (SWEEPRAT) is defined as the number of chord lengths from the leading edge of the root to the leading edge of the wing tip (see diagram). The stability factor (STABFAC) is a number usually in the range of 0.02 to 0.04, the larger number correlating to greater stability. You'd probably want 0.04 for a stable floater or trainer, and 0.02 for a highly aerobatic sloper or very sensitive F3B 'ship.

These routines can be expanded very easily with a little knowledge of BASIC. Placing the airfoil data in random access text files on disk or in DATA statements is a good start, and sailplane design programs using high resolution graphics are also a possibility.

Don't be afraid to experiment! Using the same airfoils and sweep ratio, manipulate the stability factor and watch the required geometric twist change. When the result is positive the tip is set to a lower angle of attack than the root. You would usually not want to see a negative number here if using sweepback. Or use a different root section and see how much more or less sweep is required to remain at a particular level of stability. A positive number here means sweepback. Try to keep the sweep ratio not too much bigger than two, otherwise severe tip stalling may result from cross span flow. Watch for "DIVISION BY ZERO ERROR" messages.

Just to get you started, we figured the twist required for Curt Weller's Elfe 2 (see the diagram again). This tailless design has a sweep ratio of 1.54 based on the mean (average) chord length, with an Eppler 180 at the root and Eppler 184 at the tip. The computer tells us that for a stability factor of 0.02 the wing twist should be about zero degrees; with a stability factor of 0.03 the twist should be about 1.2 degrees. The Elfe 2 uses one degree of twist to compensate for wing taper and inhibit the tips from stalling before the root. As Curt is a former F3B champion in Austria and has used the Elfe 2 in competition, you now have a little better idea as to the meaning and use of the stability factor.

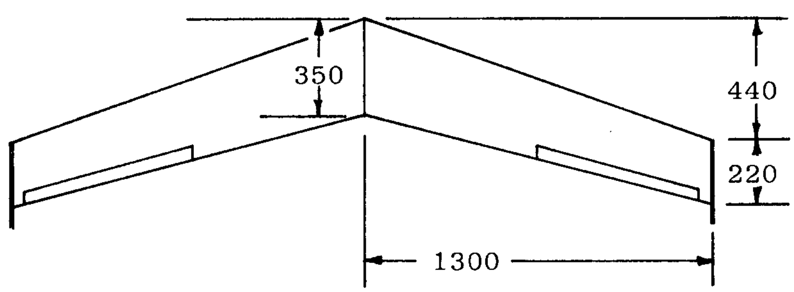
We hope you find these routines useful when designing your own tailless creations. If you don't have a computer, a calculator works just fine, too.

Some airfoil data for use in the routines:

| Section | Moment Coefficient | Zero Lift Angle |
|---|---|---|
| Eppler 174 | -0.083 | -3.6 |
| " 176 | -0.06 | -2.79 |
| " 178 | -0.038 | -1.97 |
| " 180 | -0.016 | -1.12 |
| " 182 | 0.007 | 0.3 |
| " 184 | 0.03 | 0.52 |
| " 186 | 0.05 | 1.14 |
| " 222 | -0.0974 | -3.65 |
| " 224 | -0.0613 | -2.33 |
| " 226 | -0.0231 | -0.99 |
| " 228 | 0.0143 | 0.34 |
| " 230 | 0.0531 * | 1.73 |

* Dr. Walter Panknin recommends the use of 0.025 in place of this published value.

to find sweep ratio:
mean chord = (350 + 220)/2
= 285
SWEEPRAT = 440/285 = 1.54




| | |
|---|---|
| Zero Lift Angles | = ZROOT, ZTIP |
| Moment Coefficients | = MROOT, MTIP |
| Stability Factor | = STABFAC |
| Sweep Ratio | = SWEEPRAT |
| Aerodynamic Twist | = AEROTWIST |
| Geometric Twist | = GEOTWIST |
| Total Twist | = TWIST |

```
10000  REM ** TWIST ROUTINE **
10010  CM = (MROOT + MTIP) / 2 :
       REM * AVERAGE MOMENT COEFFICIENT
10020  TWIST = (190 * (STABFAC - CM)) /
       SWEEPRAT : REM * TOTAL TWIST
10030  AEROTWIST = ZTIP - ZROOT :
       REM * AERODYNAMIC TWIST
10040  GEOTWIST = TWIST - AEROTWIST :
       REM * GEOMETRIC TWIST REQ'D
10050  REM ** BUILD WITH GEOTWIST **
```

---

```
20000  REM ** SWEEP ROUTINE **
20010  CM = (MROOT + MTIP) / 2 :
       REM * AVERAGE MOMENT COEFFICIENT
20020  AEROTWIST = ZTIP - ZROOT :
       REM * AERODYNAMIC TWIST
20030  TWIST = GEOTWIST + AEROTWIST :
       REM * TOTAL TWIST
20040  SWEEPRAT = (190 * (STABFAC - CM)) /
       TWIST : REM * SWEEP RATIO
20050  REM ** BUILD WITH SWEEPRAT **
```

## THIES SWEEP AND TWIST

```
10    REM   COMPUTES SWEEP RATIO
20    REM   WHEN NO TWIST IS USED
30    TEXT
40    HOME
50    PRINT "SWEEP RATIO"
60    PRINT "----- -----"
70    FOR X = 0 TO 2000: NEXT X
80    HOME
90    PRINT "Enter the Stability Factor desired"
100   PRINT "(Usually 0.02 to 0.04)       ": INPUT SF
110   PRINT "Enter the Moment Coefficient of the rootsection":
      INPUT M1
120   PRINT "Enter the Zero Lift Angle of the root   section":
      INPUT Z1
130   PRINT "Enter the Moment Coefficient of the tip section":
      INPUT M2
140   PRINT "Enter the Zero Lift Angle of the tip    section":
      INPUT Z2
150   DZ =  - Z1 + Z2
160   CM = (M1 + M2) / 2
170   SR = (190 * ( - CM + SF)) / DZ
180   PRINT "Sweep Ratio = ";SR
190   PRINT : PRINT "Another sweep ratio? ";: GET A$: IF A$ <  >
      "Y" AND A$ <  > "N" THEN  HOME : GOTO 190
200   IF A$ = "Y" THEN  GOTO 80
210   IF A$ = "N" THEN  TEXT : HOME : END
220   REM  COMPUTES TWIST
230   REM  BASED ON
240   REM  SWEEP RATIO
250   TEXT
260   HOME
270   PRINT "TWIST"
280   PRINT "-----"
290   FOR X = 0 TO 1000: NEXT X
300   HOME
310   PRINT "Enter Sweep Ratio": INPUT SR
320   PRINT "Enter Stability Factor"
330   PRINT "(usually 0.02 - 0.04)       ": INPUT SF
340   PRINT "Enter the Moment Coefficient of the rootsection":
      INPUT M1
350   PRINT "Enter the Zero Lift Angle of the root   section":
      INPUT Z1
360   PRINT "Enter the Moment Coefficient of the tip section":
      INPUT M2
370   PRINT "Enter the Zero Lift Angle of the tip    section":
      INPUT Z2
380   CM = (M1 + M2) / 2
390   TWIST = (190 * ( - CM + SF)) / SR
400   NULL =  - Z1 + Z2:SCHRANK = TWIST - NULL
410   IF SCHRANK > 0 AND SCHRANK < .001 THEN SCHRANK = 0
420   IF SCHRANK < 0 AND SCHRANK >  - .001 THEN SCHRANK = 0
```

```
430  IF SCHRANK = 0 THEN  GOTO 460
440  PRINT "Final twist = ";SCHRANK;" Degrees"
450  GOTO 470
460  PRINT "Final Twist = 0.0 Degrees"
470  PRINT : PRINT "Another combination? ";: GET A$: IF A$ <  >
     "Y" AND A$ <  > "N" THEN  VTAB (15): GOTO 470
480  IF A$ = "Y" THEN  GOTO 300
490  TEXT : HOME : END
```

# 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.

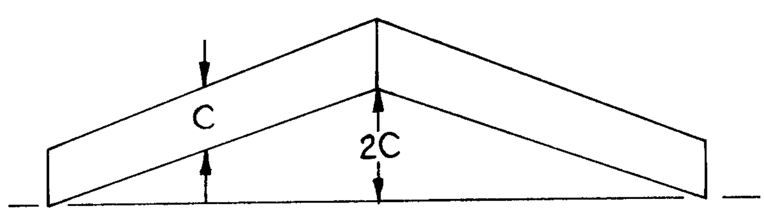
The demise of the YB-49 program probably was not due to the crash. Jack Northrop stated that while the YB-49 had won the competition with the B-36, the Air Force wanted the production lines to be at General Dynamics in Texas. There was a merger demand from the secretary of the Air Force, Northrop claimed 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!

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## 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.

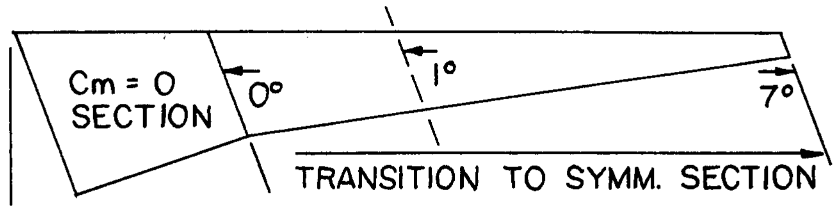
# TWIST GEOMETRY FOR SWEPT FLYING WINGS

Swept 'wings can make use of a variety of airfoils, so long as the download at the wingtips counteracts the pitching moment of the lifting surface and provides stability. The wing, therefore, usually incorporates aerodynamic and/or geometric twist, and this month we'll talk about three twist techniques.

To look at the Horten IV or Horten VI is to gaze upon pure beauty. How were the Hortens able to achieve the stability required for flight, much less maneuverability in thermals? Dr. Reimar Horten explains it is a matter of using a root section with no pitching moment, a symmetrical tip section, and the proper amount of twist.[1]

The wing twist method used by the Hortens allows the wing to stall at one third half span, at the location of both center of pressure and center of gravity. This has several beneficial effects: (1) the 'wing can be trimmed easily with small amounts of elevator movement, (2) ailerons remain effective past stalling, and (3) adverse yaw is minimized. With regard this last point: be aware the Hortens used two sets of ailerons and the aileron differential was two way. In a left turn the outboard left aileron went up $20^{o}$, the inboard $2^{o}$ up, the inboard right went down $20^{o}$, the outboard $2^{o}$ down. The ailerons also moved differentially during elevator deflections. Stability and lift distribution were thus maintained during a variety of flight regimes.

The Horten lift distribution can be fairly well duplicated in a model by using the airfoils described above and a total twist of $7^{o}$. Build the wing so the first 25% of the half span uses the zero moment section. The remainder of the wing transitions from the root section to a thinner symmetrical section at the wing tip. No twist is used for the first 25% of the half span, one degree is used at the 50% point, and seven degrees is built in at the tip.




If you're constructing with foam, the outer 75% of the half span can be cut in one piece, achieving proper twist and transition of the wing sections at the same time. Using a sufficient number of shims, simply twist the sheet of foam the correct amount in the <u>opposite</u> direction to that needed for the finished wing. Weight it down for cutting. Place the root and tip templates on the ends <u>with no twist relative to the work surface</u>. Once the core is cut the shims are removed and the wing is constructed on the foam beds, as usual. With the beds lying on the flat surface the proper twist is built in!

Model sailplanes using the Horten twist method and keeping the same aspect ratios and taper as the originals will probably suffer from the very low Reynolds number at the wing tips, even in quarter scale. Be aware and beware!

One final thing about the Horten wings - you'll notice some of the Horten designs have "bat-tails". If you plot out the quarter chord line for these designs you'll see it bends and meets the aircraft center line at $90^{\circ}$ on the Horten IV, and sweeps forward at the center on the VI. Because of the angle at which the leading edges meet there is a loss of lift in the center section, but the bat-tail is a means of reducing this effect. The lift gradient of the Horten VI compared *favorably with those of conventional* sailplanes.

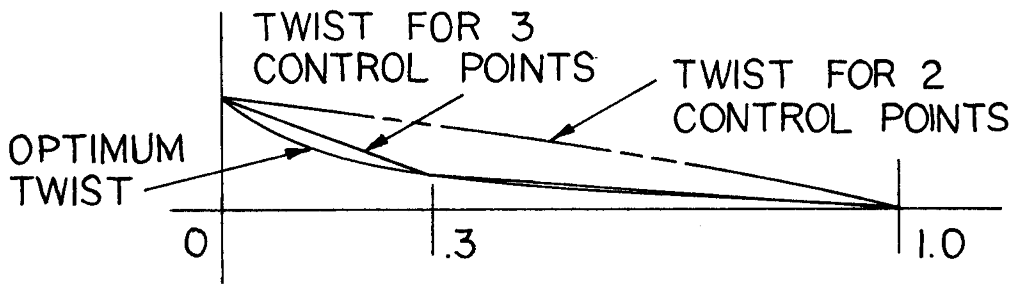
Irv Culver, retired from the Lockheed "Skunk Works", has presented a lift distribution and wing twist method different from that of the Hortens.[2] While the Hortens place the twist toward the wing tips, Culver puts the twist toward the root. The goal here is to reduce induced drag and achieve optimum span loading.

Culver's method is not so simple (!) as that of the Hortens, as it involves a formula which requires that overall design lift coefficient, aspect ratio, sweep angle of half chord line, and zero lift angles of the sections used be known and specified.

$$\alpha^{\circ}_{RT} = C_{LD} \cdot \beta^{\circ}_{\frac{1}{2}c} \cdot \pi \cdot \left(1 - \frac{1}{AR+1}\right) \cdot \frac{1}{\left(\frac{2\pi}{1+\frac{2}{AR}}\right)}$$

$$\alpha^{\circ}_{S} = \alpha^{\circ}_{RT} \cdot (1 - STA)^{\frac{AR+2\pi}{2\pi}}$$

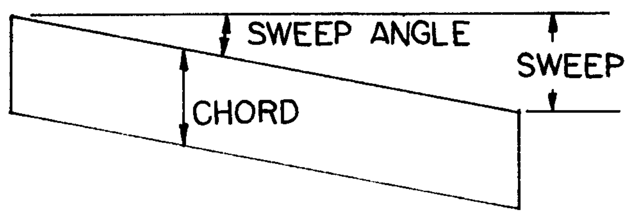
Typically, Culver's method relies on three control points - root, 30% half span, and tip.




The twist configuration advocated by Culver is easily accomplished with foam core construction, a definite advantage. Also, if a section with high coefficient of lift is chosen, trimming for high speed can still be acomplished with deflection of tapered elevons. The disadvantage is adverse roll-yaw coupling - there is excessive roll when the aircraft is yawed. The solution is to bend the wing tips down, as seen on some of the Northrop 'wings.

QBE is the third method of achieving correct wing twist. QBE stands for Quick But Effective. Cutting the foam core wings couldn't be easier: align wing root template at $0^{\circ}$, set up the wing tip template at the predetermined angle, and cut the foam. A wing half can be cut in one piece with straight taper and straight twist built in. The real secret is in determining what angle to use when aligning the wing tip template on the foam.

There is a formula, based on zero lift angles, moment coefficients, sweep ratio, and a stability factor (see OTW #5, "Computer Programs for Determining Sweep and Twist), but here are a few suggestions from designs which fly well: (1) Eppler 174 root, Eppler 182 tip, constant chord, wing swept 1.5 chord lengths measured at the tip, $4^\circ$ twist; (2) Eppler 180 root, Eppler 184 tip, aspect ratio of 9.1, $20^\circ$ leading edge sweep, $1^\circ$ twist; (3) Eppler 222 root, Eppler 230 tip, constant chord, wing swept 1.5 chord lengths measured at the tip, $0^\circ$; and (4) Eppler 224 root, Eppler 230 tip, constant chord, wing swept 1.1 chord lengths measured at the tips, $0^\circ$ twist.[3]




All through the above discussion we've talked about foam core construction - because it's both accurate and fast. Foam core construction promotes rapid design evolution. Experiment and share your findings with others!

1. The bulk of this information came from an article by Jan Scott of the Vintage Sailplane Association, originally published in The Bungee Cord, and from Dr. Martin Lichte's book "Nurflugelmodelle". Additional information can be found in TWITT Newsletter #10.

2. TWITT Newsletter #4.

3. For further information, see MTB (Modell-Technik-Berater) 1/2; these were originally published separately, but are now under one cover; available directly from the publisher: Verlag fur Technik und Handwerk GMbH.

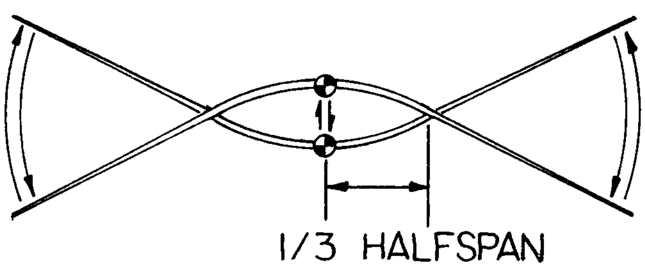
## CULVER TWIST DISTRIBUTION

```
10      PI = 3.141592654
100     PRINT "Enter the design lift coefficient": INPUT CL
200     PRINT "Enter the wing's aspect ratio": INPUT AR
300     PRINT "Enter the sweep angle of the half chord line, in
        degrees": INPUT SA
1000    X = 1 / (AR + 1):Y = (2 * PI) / (1 + (2 / AR)):TA = CL *
        SA * PI * (1 - X) * (1 / Y)
1200    PRINT TA
1500    FOR ST = 0 TO 1 STEP .1
2000    Z = (AR + (2 * PI)) / (2 * PI):AS = TA * ((1 - ST) ^ Z)
2250    PRINT ST,AS
2500    NEXT ST
```

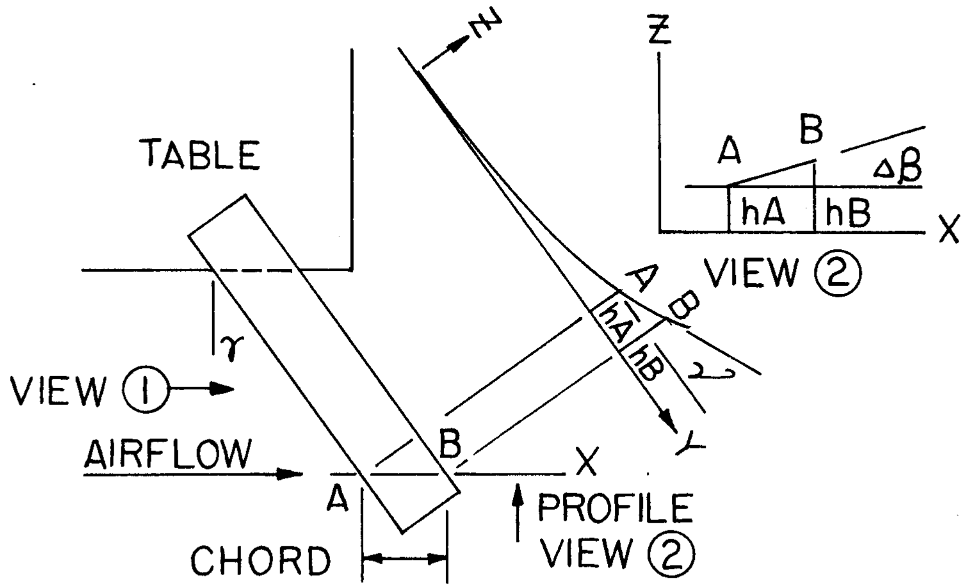
## A METHOD OF FLUTTER SUPPRESSION

Swept wing tailless sometimes suffer from flutter at high speed due to a lack of torsional rigidity. The outcome of this flutter is either a reduction in flight speed or destruction of the aircraft.
Dr. Martin Lichte has written an article describing both the flutter and a solution. Published in DELTA #6, the following is a condensation from the German text:

The first drawings show the type of flutter which swept tailless can experience. Notice the front view shows one point on each wing panel which remains motionless, while the side view, which describes the 'wing's path through the air, clearly illustrates the vertical movement of the CG.




Before a remedy can be prescribed we must find the reason for the flutter. Take a piece of sheet balsa and extend 3/4 of it past the edge of a table. "Sweep" the sheet to some angle relative to the table edge, say $20^{\circ}$, and place a flat object, like a book, on the end of the sheet which is resting on the table. If you now lift or depress the free end of the sheet you will see an interesting thing happen; the effective angle of attack of the tip changes, as shown in the next drawing.




There is a twist imparted on the wing by the geometry of the bending. For the technically minded who might be reading this,

$$\Delta\beta = \arctan(\sin\gamma * \tan\nu)$$

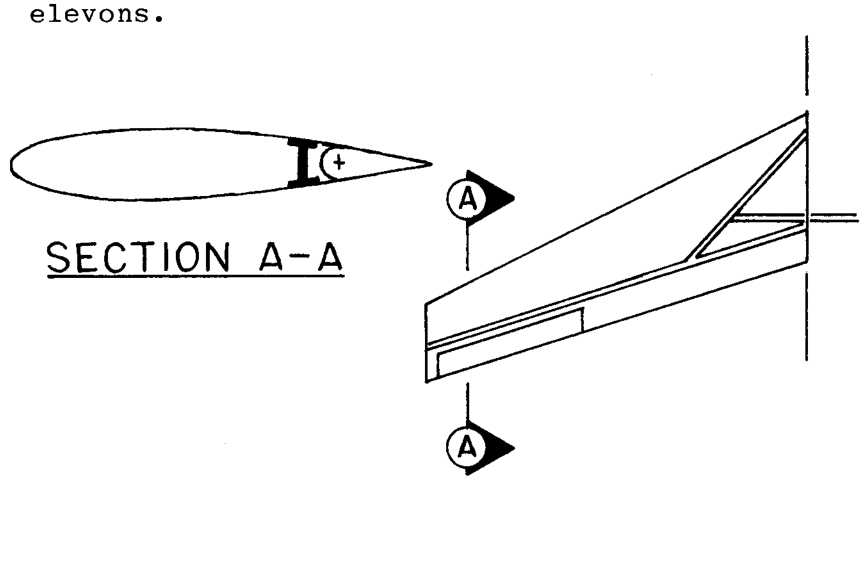
where $\beta$ = effective angle of attack

This means if you raise the tip 5° when the sweep angle is 20° the resulting change in angle of attack will be 1.7139°. It would appear the increasingly negative angle of attack as the wing is raised would force the wing back down to where it belongs, but this is not what happens. Rather, the wing continues upward until the rigidity of the structure stops the movement. The wing then flexes downward and travels past the point of origin. At some point the end of the wing will again be forced back up by the strength of the structure, and the cycle repeats. This bending of the wing is harmonic in nature and will increase in amplitude as long as the aircraft's speed remains above the flutter threshold, eventually precipitating structural failure. Interestingly, the frequency of the flutter can be changed by changing the mass of the wing - increase the mass and the bending will occur more slowly, decrease the mass and it will speed up.

Tailed airplanes usually don't experience this type of flutter because of the tremendous damping forces exerted by the fuselage and tail assembly. This means one of the most effective ways of dealing with this problem is to simply add a fuselage and tail assembly to the wing - but that would be cheating!

The solution to the problem does not lie in finding a new airfoil for the wingtip, as the basis of the problem does not lie there. An ingenious person may be able to come up with an electronic device to act as a damper, automatically moving the elevons to counteract the otherwise increasing amplitude of the bending and resulting torsion. But instead of taking up time, money, space, and weight with electronic gear it would be better to find a structural solution which could be incorporated during the building of the aircraft structure. Some reduction in flutter can be had by using winglets, for example... but read on!

There is no way all of the bending can be eliminated because there are no perfectly rigid materials, but we can use more rigid materials and place the rigidity where it will do the most good. The drawing below shows the solution presented by Dr. Lichte. The carbon fiber spar is placed well back, near the trailing edge, just in front of the elevons.



When the spar is placed to the rear of the airfoil it counteracts the torsion produced by the bending of the wing and the angle of attack of the tip is much more resistant to change. A fully sheeted foam core wing with this type spar system is very resistant to flutter even without winglets. A retrofit of this spar system would be very difficult in an existing 'wing, but what better reason to build a new one?

Dr. Lichte's article supported an idea presented by Ken Bates in The White Sheet #7 (February/March 1982). Ken's article dealt with some stability problems he was experiencing with his swept wing tailless designs, and he presented the idea of the rearward spar position as a means of controlling the torsion brought about by wing flex. Although Ken didn't talk specifically about this type of flutter, the underlying problem is identical to that presented by Dr. Lichte, and the solution is just as viable. Ken did mention some other alternatives: use (1) lots of taper, (2) thicker airfoils, or (3) lower aspect ratios. But each of these solutions has a negative effect with which you might not want to deal.

DELTA is the magazine of FSV Versmold, a German club which flies only tailless 'craft.

*The White Sheet, edited by Sean Walbank, is* the magazine of the White Sheet Radio Flying Club, a group heavily involved in slope soaring. Their flying site is a hill overlooking White Sheet Downs, a short distance northeast of Sherborne.

# TAILLESS, CANARD, & CONVENTIONAL DESIGNS... A DISCUSSION OF PERFORMANCE POTENTIAL

From TWITT's (The Wing Is The Thing) Newsletter #28, October, 1988:

## NOT A TAILLESS FAN

Victor Mead Saudek of Los Angeles writes:

...I shall make a few comments on your TWITT movement at this point: It has been very well established that nothing in the way of sailplanes can be cleaner than the conventional tail-in-the-rear configuration. To claim otherwise is to allow emotions to overcome hard won knowledge. With the prospect of making even incremental gains in performance giving one manufacturer great increases in sales you can bet the farm and your family that G. Weibel, Klaus Holighaus and others have examined this field very diligently. It is true that some features have recently been discovered - such as Les(?) Schueman(?) who figured out the double sweep back near the wing tip - and Holighaus now builds the Discus, but this is a small advantage. You should realize that when racing sailplanes are costing $45,000 in the US, there are great incentives to examine every possible detail to get an advantage.

Recall the idea of tail-first concepts by Burt Rutan and how they were advertised as being "stable" and "clean." Well, it isn't so and Technical Soaring for July 1988 has an article on the subject: "Canards: the Myths and the Realities" by Albert W. Blackburn. Any way you cut it, the forward surface should be several times the aft surface area for performance. The reasons for this have long been known. And the tailless designs are inherently poorer than tailfirst! All-wing aircraft have tails - the reflexed trailing edge of the airfoil - but this is too close to the lifting part of the wing and must always reduce that lift. With a smaller surface further aft, the tail can balance the overturning (tendency to dive) moment of the airfoil with a light downward load and little drag while the wing can have an optimum low drag airfoil.

To increase L/D of sailplanes one can reduce the waviness of airfoil surfaces (see Soaring, Dec 1987), use endplates on wingtips (carefully) and minimize interference drag at the intersections (wing-to-fuselage). The next big step will be active boundary layer control (using solar cells?) which should give L/D of 100 or so. If I haven't convinced you, I am not surprised or sad unless you invest too much money in the chasing of the tailless "Will of the Wisp."

Vic Saudek

TWITT Editor's Comments:

It seems naive to advance non-use as proof of lack of merit. I must candidly confess my ignorance of the intricacies of sailplane design, but areas of technology with which I am familiar - and there are a few of those - are littered with meritorious ideas which are simply left unused. Some are very complicated to analyze (e.g. free-piston engines) while others cannot leap the retooling barrier; others are neglected out of sheer ignorance. In this connection, the high cost and low sales volume of high-performance sailplanes would seem to provide a disincentive to innovation; I know of no practical way to squeeze "great increases in sales" from a miniscule market. There is no **technical** reason to discount tailless sailplanes *a priori*; the induced drag argument fails to consider the aircraft as a whole when considering the conventional layout. It is the downwash distribution in the wake of the aircraft - **due to the entire aircraft** - which determines whether the aircraft will have minimum induced drag. Optimum downwash gives optimum induced drag, **regardless of how it is achieved.** There is good reason to believe that a tailless design could have better induced drag, at equal span, than a conventional machine. If a wake displacement is taken into account, the advantage of the tailless airplane would seem to increase at off-design lift coefficients. The lower skin-friction drag of the tailless, and the near absence of crossflow drag in curvilinear flight, seem to favor it even more. It is not clear to me why Mr. Saudek mentions canards in connection with flying wings, as they have little in common. The basis for his claim that flying wings are somehow "worse" is equally obscure. The record of the Horten machines in international and national competition suggests very strongly that the big problem of tailless sailplanes is not aerodynamic at all - they have atrocious ground handling qualities and are vulnerable to damage during out-landings. It would actually be easier to apply boundary layer control to a tailless machine, and the availability of power for suction raises the intriguing possibility (which certain TWITTs are investigating) of using **active stabilization** as well, allowing operation with the cg behind the neutral point of the aircraft.

Marc DePiolenc

And a comment from Klaus Savier, as well, in Newsletter #29:

In engineering it is simply performance and cost which rule. If one configuration consistently shows better performance than others, it is wise to accept the fact that this configuration is better. Aerodynamic performance cannot be evaluated adequately by looking at skin friction drag and induced drag alone; there is more to the story.

Most canard configured airplanes generate a drag problem during turning flight, and thus are not a good choice for an airplane which is required to turn 80% of the time, i.e. sailplanes. This problem does not disqualify canards when they are evaluated on a broader spectrum. For the past seven years, general aviation aircraft performance has been meticulously measured and evaluated at the CAFE race in Santa Rosa, CA. CAFE stands for Comparative Aircraft Flight Efficiency, and we score:

$$\text{mph}^{1.25} \times \text{payload}^{0.75} \times \text{mpg},$$

which can also be written

$$\text{mph}^{2.25} \times \text{payload}^{0.75}/\text{gph}.$$

As you can see, speed and efficiency are of greatest value. The airplanes are flown at or near gross weight around a 400 km course - climbing, descending and turning around pylons. There is no doubt that low drag is highly desirable in this event, yet it has always been won by canard configured airplanes. I entered the CAFE race four years ago. Since then the three top places in the two-seat category have always been taken by canards! This year Gary Hertzler (VariEze), Gene Sheehan (Q200) and I scored within 3% of each other. Fourth place went to Mike Maxwell and co-pilot Ray Cote in Mike's meticulously race-prepared Lancair. Its score was 25% lower!

I would like to invite all believers in the "old configuration" to perfrom in the CAFE race or fly your old configuration nonstop, unrefuelled around the world. My hat and goggles to you if you win. Until then: put up or shut up.

Klaus Savier

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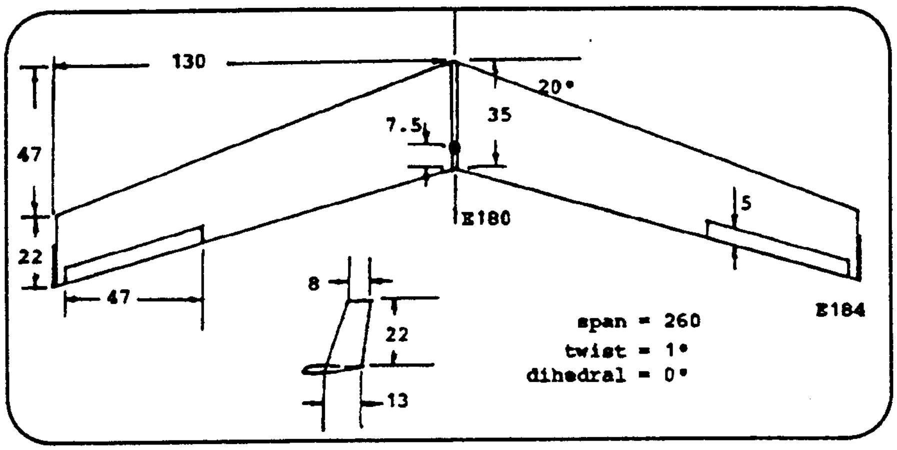
All of the above information concerns full sized aircraft, particularly the powered type. We feel, however, that much of what is said is applicable to the improvement of our R/C sailplanes. Of particular note are the topics of boundary layer control, drag measurement, and CG location. We're hoping that you will be able to pick up a few other enticing tidbits and incorporate something new in your next project.

## FOUR GERMAN 'WINGS

Our own interest in flying wings is now five years old. (But our piles of accumulated information would make it appear we've held this interest for a substantially longer period of time.) While going through our files recently, we marveled at the improvements in flying wing design which we've seen over this relatively short period, and thought perhaps a brief description of several representative 'wings would be of interest.

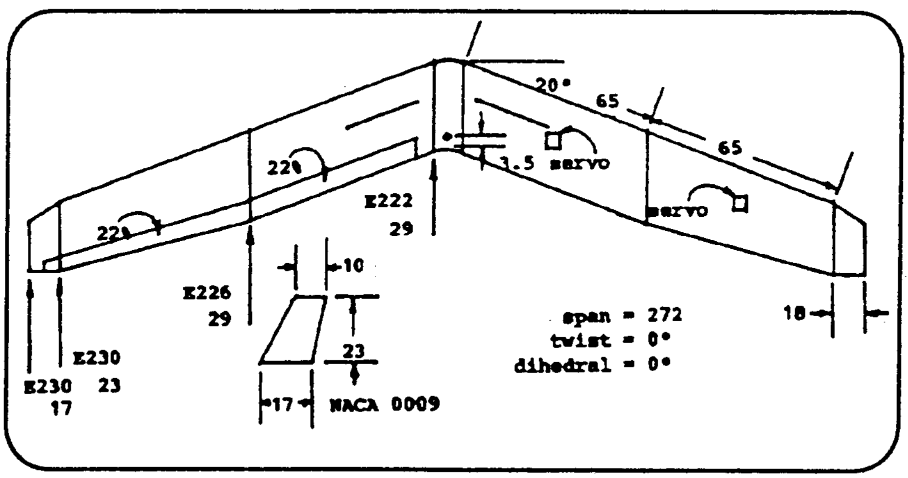



ELFE II, 1984

Curt Weller's Elfe II has most probably had a greater effect on flying wing advocates than any other design, for it announced to the world that high performance swept wings are possible. Some of its performance characteristics are no doubt due to the fact Curt is a former Austrian F3B champion.

The Elfe II is easily constructed of foam/balsa/fiberglass using the dimensions shown here. Elevons are used as control surfaces and the speed range is quite broad even though there are no flaps. The elevon servos are mounted in the wings. No bridle is necessary and so only one tow hook is used. The plywood keel serves the dual purpose of mounting surface for the tow hook and hand hold during launch. We have seen the fins both glued securely to the wing and mounted with flat head screws. The screw mounting technique allows removal for transport and easy replacement in case of damage.

Take note of the airfoils used: the Eppler 180 at the root and the 184 at the tip. These are good choices as they are both relatively low drag sections; the E 180 has a good lift coefficient, and the E 184 does not have excessive reflex. The use of these two sections also allowed Curt to use a minimum of wing twist to assure stability - just one degree. The Elfe II needs to be flown at all times, as it will not search out thermals like many plank designs. It is maneuverable and fast, but is also a very capable floater when the need arises. It does well in F3B and thermal duration contests, and at least one flyer has entered an Elfe II in a slope race.

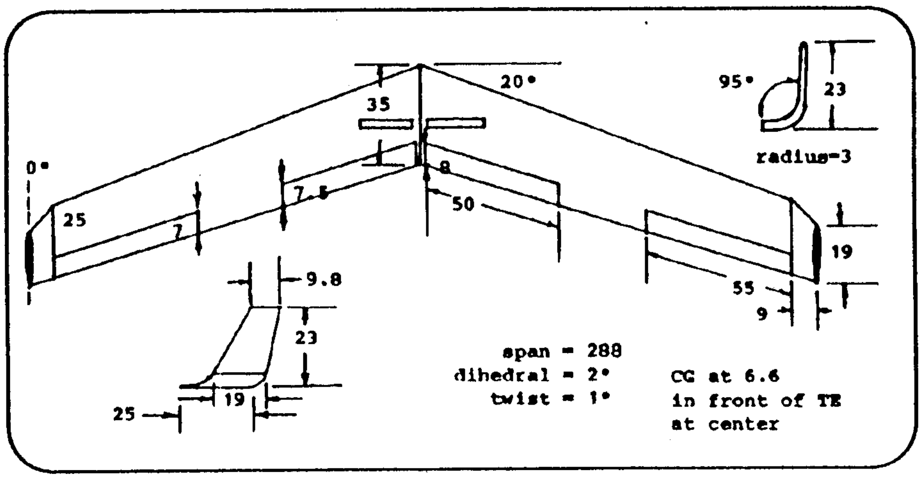



NURFLUGEL, 1986

"Nurflugel" is German for "only wing," and it's never been clear to us whether this is the actual name of this design or just a generic term applied to it. Designed by Klaus Brunswicker, this 'wing features flaps, spoilers, and pseudo-Scheumann tips, and seems well suited to thermal-duration tasks.

Significant is the use of the Eppler 222 - 230 series of airfoils. These sections were designed specifically for swept flying wings, and the use of the E 222, 226 and 230 on this design are an indication of what can be done with these airfoils. The E 222 is an undercambered section with good lift, and the E 230 can provide sufficient stability for the design without the necessity of twist.

The separate fuselage provides adequate room for batteries and receiver, and is shaped to promote a smooth connection between the quarter chord lines of the two wings. This is beneficial to the lift distribution and improves thermal performance.




JUST IN TIME, 1987

Hans-Jurgen Unverferth for some time wrote a flying wing column for the German magazine Flug- und Modelltechnik (FMT). He is a proponent of flying wings for F3B, and over the past few years has developed several designs, each a better performer than the previous. Following the evolution of Hans-Jurgen's designs is rather interesting, and demonstrates quantum leaps in design strategy.

"Pirx" (1985), an earlier design, used the Eppler 224 section at the root and the E 230 at the tip, with $15.5^{o}$ of leading edge sweep and no twist. Elevons were the only control surfaces used.

"Just In Time" was nearly a complete departure from "Pirx," retaining only similar overall dimensions and wing sweep. Using a symmetrical Quabeck section of 9% thickness, and one degree of twist, Hans-Jurgen turned to flaps and airbrakes for speed and glide path control. Pseudo-Scheumann tips, but in a slightly different form than "Nurflugel," were used. "Just In Time" sported curved tips which blended the wing into winglets. The winglets were mounted at $95^{o}$, maintaining a good lift distribution and minimizing tip losses.

"Ceozwo" ("$CO^2$"), Hans-Jurgen's newest endeavor, uses a constant chord wing and a pod fuselage. Elevons and flaps, like those on "Just In Time," are retained. We don't have much more physical information on "Ceozwo," but its performance at the 17th Ludwig-Kramer-Cup (F3B) held in Dortmund, Germany, allowed Hans-Jurgen to score 8274 points. The top flyer in the contest, with a tailed "Albatros," scored 8777.

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The above information was compiled from: Model Aviation; DELTA, the magazine of FSV Versmold, #5 and #7; Flug- und Modelltechnik (FMT), published by Verlag fur Technik und Handwerk GmbH; and The White Sheet (White Sheet Radio Flying Club, England) FW Special #2.

# NOTES ON PLANKS

For the past two decades the most popular tailless RC sailplanes have been planks, and there are many full size plans available.

A common plank design consists of a constant chord wing with no sweep, a centrally mounted elevator, and a large rudder. Planks of this type have a very simple structure that lends itself to rapid building. Stability in pitch is achieved by reflexing the last 20 to 25% of the airfoil and having a forward CG.

The reflexed sections used by planks are essentially one speed airfoils. When flying too slow the forward CG pitches the model down and speed increases; when flown too fast the reflex pitches the model up and speed decreases. Planks are thus very stable and make great trainers - both of us learned to fly proportional with a plank, Dave Jones' "Raven MB."

Plank type 'wings fly about 50% faster than conventional airplanes of the same wing loading, but with their inherently draggy reflexed airfoil their glide ratio is not good, and dead air duration is about one half that of a conventional sailplane. Yet a good plank, in capable hands, will outclimb a conventional sailplane in a thermal! Planks have a low wing loading, can turn tightly, and some, like the Raven, will automatically center themselves in a thermal, hands off!

The stable reflexed section brings with it two unique problems:

(1) It's quite disconcerting to try to dethermalize a plank by diving. The wing has a positive camber with the elevator down and so its lift increases. As the 'wing gains speed the increased lift can actually offset the down elevator being applied. We've often found ourselves in nearly level relatively high speed flight with moderate down elevator! Ken Bates recommends diving inverted when dethermalizing his "Windlord." (Plans available through Model Aviation.)

(2) Thermaling with full up trim sets the turn and lowers flight speed. But this increases the effective reflex and applies a big down load to the wing - just the opposite of what you want in a thermal turn when attempting to make the best use of available lift.

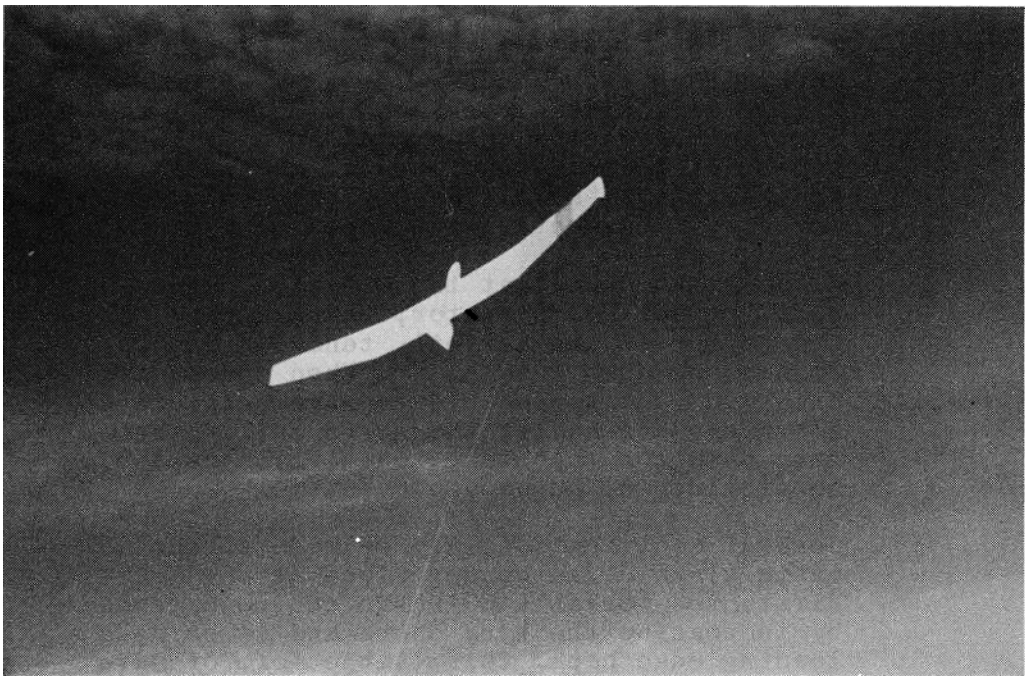
Some flyers of both full size and model size planks, rather than relying on elevator trim which is always drag producing, have experimented with a sliding weight device that adjusts trim for high speed and thermaling flight modes. The trim on our Ravens is noticeably changed with the addition or removal of a 1/4" cube of lead, and so it doesn't take much weight shifting to change trim significantly. The system works well but entails an added mechanism.

Always make sure that the elevator servos pull for up. The elevator, being a part of the reflex of the airfoil, tends to have a consistent down load on it. When speeds are high you want to be able to have reliable up elevator, and having the servo pull rather than push for that function eliminates the possibility of pushrod buckle.

Several modifications can be made to the basic plank deign we described at the start. First, the workable CG range can be extended by increasing the wing chord and sweeping the leading edge back. This is the form of Dave Jones' "Blackbird 2M," spoken of so often in this column. A second modification of the basic plank involves sweeping the trailing edge forward while maintaining a straight leading edge. The resulting planform is good for maintaining effective aileron control and nearly eliminates any pitch changes brought about by aileron differential. Jim Marske's full size Pioneer II is an excellent example of this planform.

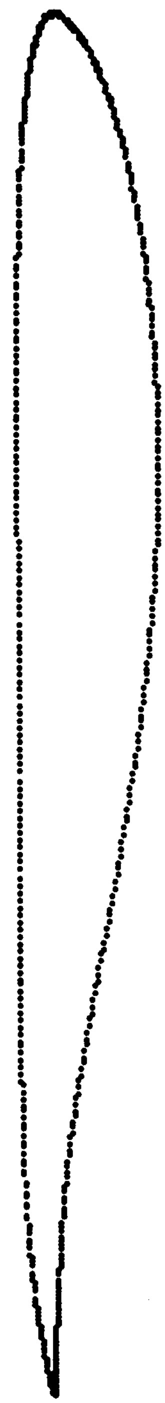
Contrary to popular opinion, flaps can be used on planks. While tows are straight and steep without them, the climb rate is improved. Also, they are effective landing aids. Their area should be no more than 5% of the wing. Install them on the bottom wing surface at 40% local chord; they won't affect pitch much when located there. Deflections of $40^o$ are effective. Flaps should <u>not</u> be used when thermaling!

A final comment: You must adhere to the FAI minimum wing loading of 3.96 oz./$ft^2$ when competing in AMA events, and its very easy to build planks well below that minimum.



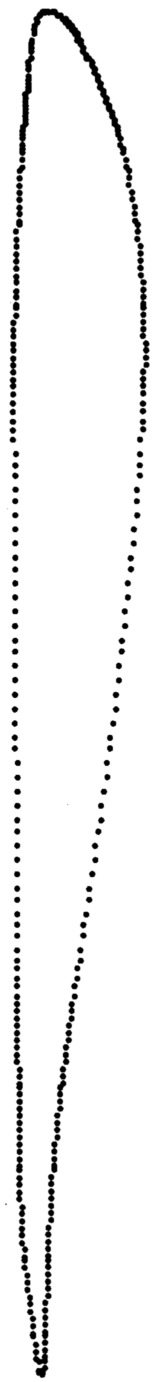
AR 193-S75

| X | Y |
|---|---|
| 100.0 | 0.0 |
| 99.661 | 0.0 |
| 98.674 | 0.0 |
| 97.108 | 0.018 |
| 95.023 | 0.113 |
| 92.452 | 0.227 |
| 89.414 | 0.398 |
| 85.945 | 0.625 |
| 82.096 | 1.023 |
| 77.923 | 1.675 |
| 73.484 | 2.462 |
| 68.839 | 3.286 |
| 64.052 | 4.265 |
| 59.186 | 5.052 |
| 54.306 | 5.824 |
| 49.458 | 6.485 |
| 44.673 | 7.005 |
| 39.979 | 7.363 |
| 35.402 | 7.55 |
| 30.967 | 7.566 |
| 26.696 | 7.418 |
| 22.62 | 7.131 |
| 18.78 | 6.724 |
| 15.218 | 6.215 |
| 11.967 | 5.6 |
| 9.061 | 4.91 |
| 6.525 | 4.157 |
| 4.383 | 3.356 |
| 2.652 | 2.528 |
| 1.344 | 1.699 |
| 0.465 | 0.901 |
| 0.026 | 0.189 |
| 0.0 | 0.0 |
| 0.129 | -0.379 |
| 0.819 | -0.862 |
| 2.044 | -1.312 |
| 3.791 | -1.699 |
| 6.049 | -2.019 |
| 8.801 | -2.27 |
| 12.026 | -2.453 |
| 15.697 | -2.576 |
| 19.778 | -2.646 |
| 24.227 | -2.672 |
| 28.998 | -2.665 |
| 34.035 | -2.636 |
| 39.28 | -2.593 |
| 44.672 | -2.547 |
| 50.145 | -2.504 |
| 55.63 | -2.472 |
| 61.059 | -2.454 |
| 66.364 | -2.452 |
| 71.479 | -2.468 |
| 76.339 | -2.431 |
| 80.882 | -2.315 |
| 85.05 | -2.171 |
| 88.788 | -1.884 |
| 92.048 | -1.553 |
| 94.794 | -1.165 |
| 97.003 | -0.773 |
| 98.64 | -0.455 |
| 99.655 | -0.227 |
| 100.0 | 0.0 |



## CJ-25$^2$-09

| X | Y |
|---|---|
| 100.0 | 0.0 |
| 96.092 | 0.227 |
| 92.144 | 0.372 |
| 88.191 | 0.513 |
| 84.238 | 0.727 |
| 82.618 | 0.888 |
| 80.286 | 1.088 |
| 78.535 | 1.296 |
| 76.782 | 1.53 |
| 73.279 | 2.045 |
| 62.275 | 3.675 |
| 54.773 | 4.644 |
| 47.273 | 5.591 |
| 39.771 | 6.413 |
| 32.568 | 6.963 |
| 28.967 | 7.153 |
| 25.366 | 7.25 |
| 21.765 | 7.159 |
| 18.953 | 6.98 |
| 16.138 | 6.714 |
| 13.325 | 6.308 |
| 10.51 | 5.691 |
| 8.76 | 5.163 |
| 7.006 | 4.498 |
| 5.256 | 3.718 |
| 3.503 | 2.903 |
| 1.755 | 1.99 |
| 0.876 | 1.475 |
| 0.438 | 1.137 |
| 0.219 | 0.872 |
| 0.0 | 0.0 |
| 0.219 | -0.46 |
| 0.438 | -0.628 |
| 0.876 | -0.786 |
| 1.755 | -0.919 |
| 3.503 | -1.116 |
| 5.256 | -1.272 |
| 7.006 | -1.418 |
| 8.76 | -1.57 |
| 10.51 | -1.707 |
| 13.325 | -1.861 |
| 16.138 | -1.974 |
| 18.953 | -2.077 |
| 21.765 | -2.177 |
| 25.366 | -2.252 |
| 28.967 | -2.221 |
| 32.568 | -2.171 |
| 39.771 | -2.113 |
| 47.273 | -2.045 |
| 54.773 | -1.973 |
| 62.275 | -1.904 |
| 69.775 | -1.835 |
| 73.279 | -1.804 |
| 78.53 | -1.746 |
| 82.618 | -1.746 |
| 84.238 | -1.733 |
| 88.191 | -1.534 |
| 92.144 | -1.117 |
| 96.092 | -0.571 |
| 100.0 | 0.0 |



## SWEPT 'WING PROGRESS

Swept 'wings have gained in popularity over the last few years, and it is our opinion that several technological advances are responsible.

These advances are:

(1) an increasing number of excellent airfoils,

(2) very simple mathematical methods for computing the washout needed to provide adequate stability,

(3) better construction materials, and

(4) new and better construction methods, most notably the vacuum bag technique.

Because of these improvements the performance of swept 'wings has increased dramatically. Swept 'wings now offer the strength to survive and take advantage of full power winch launches. They are stable, maneuverable, and capable of high speed. In short, they are now very nearly the equal of their tailed counterparts, and it may not be long before they exceed that performance. When the latter does occur their popularity will shoot up even more!

Let's take a look at each of the four factors listed above...

### AIRFOILS

Radio controlled swept 'wings first started appearing in numbers during the early part of this decade. Airfoils used included the then new Eppler 174-186 series. More popular now is the Eppler 222-230 series of airfoils, especially designed for swept 'wings. Some flying wing enthusiasts have taken to modifying the airfoils of conventional sailplanes, like the Quabeck sections, for use on their wings, while others have designed their own with computer assistance.

## WING TWIST & STABILITY

It seems to be a rule of thumb that the quarter chord line sweep angle should be about 20°. Larger sweeps produce large amounts of detrimental cross span flow, smaller sweeps require more twist or reflexed sections.

In an effort to obtain stability, many designers have included large amounts of wing twist, along with reflexed tip sections, in their designs. While providing the large amount of stability the designer intended, the performance of these aircraft is usually not so good as anticipated. Heavily reflexed sections create large amounts of drag (as we saw in our discussion of planks), and excessive wing twist works against a wide speed range. The individual looking for the performance needed to compete effectively in thermal duration contests and F3B tasks will likely use airfoils which are nearly symmetrical, as the combining of undercambered and reflexed sections inherently requires more twist. Maneuverability and maximum speed range come through measured decreases in stability, not increases.

## CONSTRUCTION MATERIALS

Swept wings can make good use of new construction technologies. Two compatible goals are now being achieved with the use of composite technology - reduced weight and increased strength. The use of foam core wings is but a first step when constructing a swept 'wing. Diagonally oriented fiberglass skins, obechi veneers, Kevlar for high stress areas, and carbon fiber spar systems can all provide strength far in excess of conventional balsa and spruce construction. Well designed composite structures using these materials weigh substantially less than their wooden counterparts, while providing great increases in structural strength.

(Installing arrow shaft hinges can provide another quantum leap in both appearance and performance.)

## CONSTRUCTION METHODS

Using a vacuum bag system saves even more weight by reducing the amount of epoxy needed, and it also integrates the structure and nearly eliminates paint and other weighty finishes. Additionally, vacuum bagging provides the builder with a straight, true, and accurately constructed aircraft. Vacuum bagging a composite aircraft can result in an incredibly strong flying machine with astounding performance.

## OPTIMUM SWEEP ANGLE

Nearly all of the best performing tailless aircraft exhibit a leading edge sweep angle of $20^{o}$, and we thought it might be an interesting excercise to attempt to determine why this might be so.

As we've mentioned in a previous column, it is sometimes convenient to think of a tailless aircraft as actually having a tail by assuming the tail is a part of the wing.

The "tail" on a plank design can be considered to be the rear 20 to 25% of its reflexed airfoil.

On a swept wing, the stabilizing "tail" is the outer portion of the wing, near the tips.

A tailless airplane must have some portion of the wing capable of applying the downforce needed to counteract the pitching moment generated by the lift producing section of the wing. Planks thus use reflexed sections, swept 'wings use aerodynamic twist to provide this force.

We've previously published a set of computer routines which assist in picking airfoils for root and tip while assuring stability in pitch. With some experimentation, it's possible to design a stable swept wing with a minimum of physical (geometric) washout. Excessive washout, while providing increased stability, will make a swept 'wing behave much like a plank with excess reflex - the 'wing's speed range and maneuverability will suffer.

Those of you who have experimented with the above mentioned computer routines will have also noticed one way of reducing the amount of washout (twist) needed is to make the sweep angle greater. Unfortunately, this has three negative effects.

(1) The air moving over the wing will tend to move more toward the end of the wing, rather than the trailing edge. This is called cross span flow and is something to be avoided.

Cross span flow means the air is no longer following the airfoil; rather, it is following the spar line. The boundary layer gets very deep very fast in this situation, and laminar separation can occur at odd and unexpected places along the span. This is not only drag producing, it can be downright dangerous. Imagine separated flow over the wing tips ("tail") and the resulting loss of stability!

(2) Large amounts of sweep make steep towline launches very difficult, as any yaw is immediately translated into a large rolling force.

(3) It becomes more difficult to construct a torsionally rigid wing as sweep increases.

While planks do not suffer from any of these three problems, we want better performance than a plank has to offer. What we're looking for is sufficient sweep to improve performance substantially above that of the plank configuration while at the same time avoiding excessive sweep which will lead to further problems.

Assisting us in our search is the necessary vertical fin area. If this fin area is located on the centerline of the aircraft we will most likely need some type of boom (read "fuselage") to get the moment arm long enough. But if winglets are used we can obtain good leverage, the vortex from the wing tips can be controlled, and we can inhibit cross span flow to some extent. By using winglets we can safely get a bit more sweep into the design.

Aspect ratio is a determining factor when computing the sweep angle needed for a given level of stability. A look at the formulae shows sweep is given in terms of a ratio equal to sweep distance divided by average chord. A low aspect ratio dictates a greater angle of sweep, all other things being held constant. While a higher aspect ratio will decrease the sweep angle needed, it can also lead to frail structures, just as with conventional tailed aircraft.

So it turns out the 20° angle is a compromise, and an excellent one! Twenty degrees is enough sweep to provide stability for a number of airfoil combinations without resorting to reflexed sections over the majority of the span; it does not promote uncontrollable cross span flow; it allows steep winch launches without the worry of yaw induced roll; it does not hinder the construction of torsionally rigid wings.

**WINGLETS**

We've received several letters, and even a few 'phone calls, from RCSD readers who are designing, building, and flying their own swept 'wings. A common area of interest is "winglets," and so it is this month's topic.

Nearly all modern swept wing tailless soarers have fin area at the end of each wing. These winglets usually incorporate some sweep in their form and are mounted vertically, with their trailing edge meeting that of the wing itself.

Swept wings have some inherent directional stability. This is because as the wing yaws the span of the forward wing is effectively increased, creating more drag, while the drag of the receding wing decreases. The devilish problem which arises is yaw-roll coupling. This occurs because the forward wing creates more lift, as well as more drag, while the receding wing produces less lift. Yaw-roll coupling is not inherently bad, but it is something which needs to be kept under control.

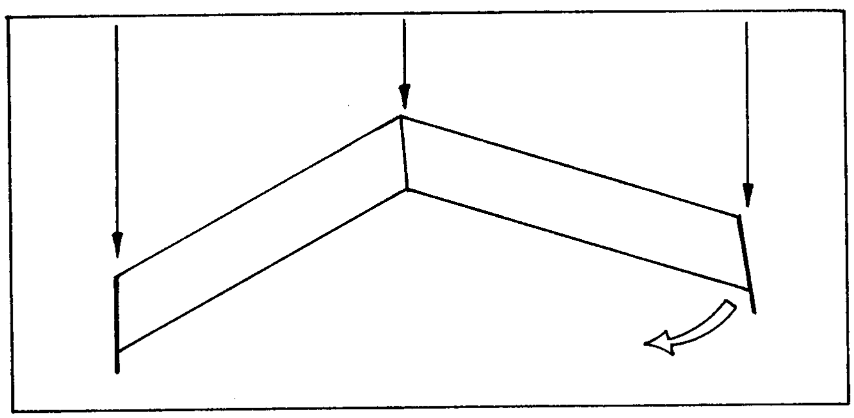
The first purpose of fin area, then, is to provide additional directional stability, hence reducing yaw and the associated roll. The second purpose is to prevent a steeply banked 'wing from sliding span-wise toward the ground.

If these were the only reasons for fin area, we'd be likely to see only a single fin mounted on the centerline of the wing, perhaps on the end of a small boom if the sweep angle is large enough.

But by splitting the fin area in two, and placing each of the resulting smaller fins at the ends of the wings, we are able to effectively inhibit the vortex usually formed there. This increases efficiency. Some designers have taken this a step further and extended the elevons all the way to the winglets, allowing the winglets to seal the outboard tips of the elevons, thus increasing their effectiveness.

Most of the winglets that we've seen extend only upward from the wing, apparently because the smaller downward projecting portion of a true Whitcomb winglet would be easily broken off during landing. These winglets are commonly made of sheet balsa, with the leading edges rounded and the trailing edges sharpened. These "flat plate" winglets are prone to stalling, and are therefore mounted parallel to the direction of flight and aircraft centerline.

Admittedly, the flat plates seem to work well and are easily constructed, but the relationship of tip fin airfoil and toe-in is certainly a topic worthy of investigation.



The above diagram shows a positively swept wing yawed slightly to the left. Notice that if the tip fins are toed in just a couple degrees then the right fin tends to correct the yaw. The left fin would similarly correct a yaw to the right. No drag penalty would be incurred at low yaw angles (compared with a flat plate mounted at 0 degrees) if the symmetrical airfoil used is chosen carefully. A list of possible sections is included at the end of this column.

In an attempt to smooth the lift distribution at the end of the wing, a few designers have tipped the winglets outwards at a 5 to 10 degree angle from the vertical. The effectiveness of this technique is probably variable.

One final note: The term "winglet" does not properly describe the tip mounted fins we've talked about here. Neither does the term "tip plate." Personally, we're rather fond of the descriptive term used by Dr. Martin Lichte in his book "Nurflugelmodelle" - "Ohren" or "ears."

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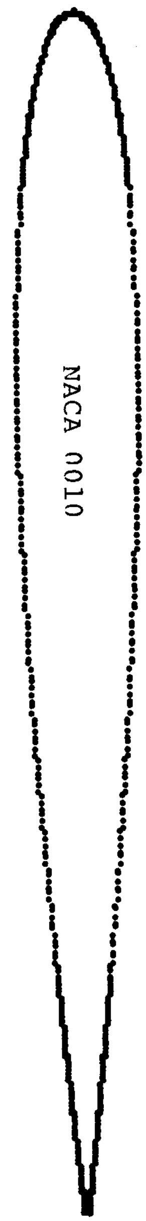
AIRFOILS OF NOTE FOR USE AS WINGLETS

NACA 0010
NACA 63-010/0
NACA 63A-010/0
HQ 0.0/10.0
RG15A-0/10

Coordinates and plots for the above sections begin on the next page. To reduce the 10% thickness to the thickness of your choice, simply multiply each Y ordinate by the suitable constant. For example, multiplying each Y ordinate by 0.9 will give the coordinates for a 9% thick section, multiplying each by 0.65 gives the coordinates for a 6.5% section.

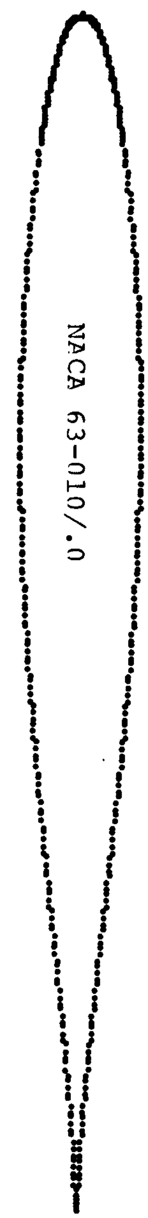
NACA 0010

| X | Y |
|---|---|
| 0.0 | 0.0000 |
| .75 | 1.2374 |
| 1.25 | 1.5782 |
| 2.5 | 2.1789 |
| 5 | 2.9622 |
| 7.5 | 3.4999 |
| 10 | 3.9023 |
| 12.5 | 4.2128 |
| 15 | 4.4543 |
| 20 | 4.7813 |
| 25 | 4.9510 |
| 30 | 5.0014 |
| 35 | 4.9572 |
| 40 | 4.8358 |
| 45 | 4.6506 |
| 50 | 4.4117 |
| 55 | 4.1270 |
| 60 | 3.8028 |
| 65 | 3.4437 |
| 70 | 3.0533 |
| 75 | 2.6336 |
| 80 | 2.1859 |
| 82.5 | 1.9517 |
| 85 | 1.7105 |
| 87.5 | 1.4621 |
| 90 | 1.2064 |
| 92.5 | 0.9432 |
| 95 | 0.6721 |
| 97.5 | 0.3929 |
| 98.75 | 0.2500 |
| 100 | 0.0000 |



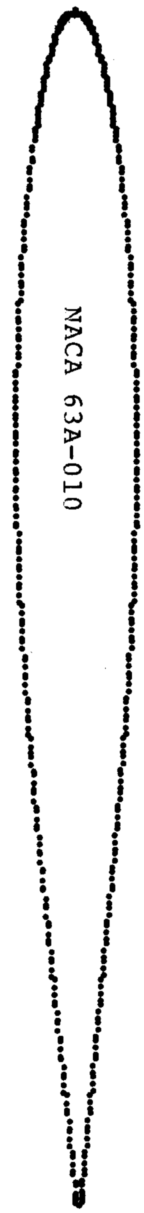
NACA 63-010

| X | Y |
|---|---|
| 0.0 | 0.000 |
| .5 | 0.829 |
| .75 | 1.004 |
| 1.25 | 1.275 |
| 2.5 | 1.756 |
| 5 | 2.440 |
| 7.5 | 2.950 |
| 10 | 3.362 |
| 15 | 3.994 |
| 20 | 4.445 |
| 25 | 4.753 |
| 30 | 4.938 |
| 35 | 5.000 |
| 40 | 4.938 |
| 50 | 4.496 |
| 60 | 3.715 |
| 70 | 2.712 |
| 80 | 1.618 |
| 85 | 1.088 |
| 90 | 0.604 |
| 95 | 0.214 |
| 100 | 0.000 |



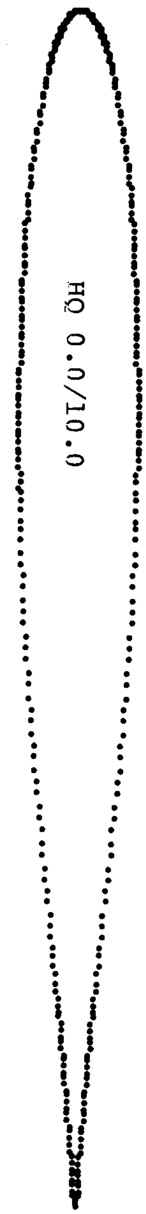
NACA 63A-010

| X | Y |
|---|---|
| 0.0 | 0.000 |
| .5 | 0.816 |
| .75 | 0.983 |
| 1.25 | 1.250 |
| 2.5 | 1.737 |
| 5 | 2.412 |
| 7.5 | 2.917 |
| 10 | 3.324 |
| 15 | 3.950 |
| 20 | 4.400 |
| 25 | 4.714 |
| 30 | 4.913 |
| 35 | 4.995 |
| 40 | 4.968 |
| 50 | 4.613 |
| 60 | 3.943 |
| 70 | 3.044 |
| 80 | 2.040 |
| 90 | 1.030 |
| 95 | 0.525 |
| 100 | 0.021 |



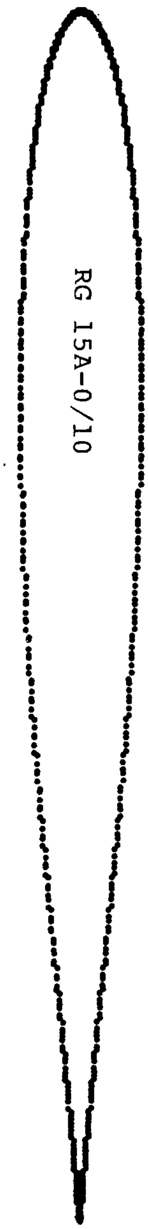
HQ-0/10

| X | Y |
|---|---|
| 0.0 | 0.000 |
| .5 | 0.722 |
| 1.25 | 1.278 |
| 2.5 | 1.889 |
| 5 | 2.667 |
| 10 | 3.556 |
| 15 | 4.222 |
| 20 | 4.556 |
| 25 | 4.778 |
| 30 | 4.889 |
| 35 | 5.000 |
| 40 | 4.833 |
| 50 | 4.556 |
| 60 | 3.778 |
| 70 | 2.778 |
| 80 | 1.722 |
| 85 | 1.167 |
| 90 | 0.778 |
| 95 | 0.333 |
| 100 | 0.000 |



RG 15A

| X | Y |
|---|---|
| 0.0000 | 0.0000 |
| 0.3049 | 0.6203 |
| 1.1040 | 1.2661 |
| 2.2646 | 1.8706 |
| 3.8801 | 2.4693 |
| 5.8987 | 3.0163 |
| 8.3313 | 3.5123 |
| 11.1535 | 3.9442 |
| 14.3469 | 4.3071 |
| 17.8876 | 4.5956 |
| 21.7489 | 4.8075 |
| 25.8995 | 4.9414 |
| 30.3054 | 4.9982 |
| 34.9280 | 4.9791 |
| 39.7260 | 4.8875 |
| 44.6543 | 4.7256 |
| 49.6654 | 4.4978 |
| 54.7148 | 4.2026 |
| 59.7459 | 3.8348 |
| 64.6897 | 3.4110 |
| 69.4954 | 2.9611 |
| 74.1168 | 2.5074 |
| 78.5038 | 2.0665 |
| 82.6063 | 1.6519 |
| 86.3751 | 1.2749 |
| 89.7635 | 0.9428 |
| 92.7258 | 0.6611 |
| 95.2171 | 0.4280 |
| 97.2166 | 0.2359 |
| 98.7164 | 0.0935 |
| 99.6695 | 0.0190 |
| 100.0000 | 0.0000 |



## TAILLESS AND F3B

Carl R. Illinik, of So. California, asked in a recent letter, "If flying wings are so good, how come they're not blowin' 'em away in F3B?" An excellent question, as there is no technical reason for a tailless sailplane to do any less well than a conventional design. From a practical standpoint, however, there are a few good reasons.

First, 'wings fly faster than conventional sailplanes of equal wing loading. If a sailplane has a glide ratio of 25 to 1 and travels forward at 25 feet per second, it will drop at 1 foot per second. If it is traveling at 50 feet per second it will drop at 2 feet per second with that same glide ratio of 25 to 1. Translated, this means if our 'wing and a conventional sailplane have the same glide ratio and are launched to the same height in "dead" air, our 'wing will be on the ground first. But it will have covered the same distance as the tailed airplane. This is not a problem in the speed or distance tasks, but it is a problem in the duration task. The new flying wings we've been seeing tend to have better glide ratios than tailed 'craft, however, so this first disadvantage is at least partially offset. The new 'wings also have camber changing capability, and as a result their scores are going up. So "practical" seems to be getting closer to "technical."

Second, although tailless performance is now very good, there is also little doubt that we still have some problems with the planform itself. We need some hard data on airfoils (particularly those with low $C_m$ and high lift), sweep vs. cross span flow, and camber changing devices which are more effective. Control systems need improvement. And because of their higher speeds and lower drag, 'wings will always need landing aids in the form of flaps and/or spoilers. So there is much yet to do in the way of advancement.

Third, we Americans tend to see F3B as only that which happens at the World Championships. Allow us to explain that statement through a single example...

The F3B pilots in Germany are rated according to a class system, and the German pilots going to the World Championships are the country's top flyers. The Germans do not fly thermal duration very much at all, they fly the F3B schedule almost exclusively, and this gives them a lot of practice in competition. The German team at the WCs, therefore, consists of the top three pilots of the last two years, and they are well practiced. Tailless F3B machines have simply not yet "come up through the ranks" of the German system. They're actually doing quite well at the local level.

Fourth, and getting more directly to the question, the top European pilots tend to be conservative when it comes to sailplane design, and are thus flying conventional tailed aircraft. The 'wings entered in competition are being flown by good pilots, but certainly not Europe's best. There was a flying wing at the '87 WCs, not entered in competition. It impressed the likes of Ralf Decker and did a 26.4 second speed run during a demonstration. Now 26.4 seconds sounds pretty good, especially when compared with the speed runs we witnessed at the NATS in Richland this summer. But, the top European pilots are consistently flying the speed run in under 21 seconds, sometimes under 18, and the record is 14.6 seconds, or some such thing, flown at a German meet.

It is our impression that current 'wings are capable of the performance required to win, but piloting skills need improvement.

The bottom line is this: Until an excellent F3B pilot can wring astounding performance from a tailless sailplane, we will continue to see tailed aircraft dominate F3B. Of course there's also the possibility that tailless sailplanes, once they dominate F3B, will be outlawed from competing in the event. Should you doubt this, look at the history of RC pylon racing!

On a slightly different but related note, Dr. Helmut Quabeck was recently asked what he thought the F3B machines of the future would look like. He drew a 100" span V-tailed canard(!), so maybe there is some movement away from conventional aircraft after all.

# A JIG FOR IMPARTING TWIST IN A FOAM CORE WING

While it may be possible to construct a swept 'wing without incorporating any twist at all, most of us would like to have a degree or two of washout to assure us that any tip stalling problems will be minor. So we've cranked in the twist as we cut our cores by simply placing the root and tip templates at an angle to each other. This method spreads the twist evenly across the semi-span of the wing.

When we consider that the wing tips are taking the place of the tail assembly, it seems immediately obvious that we should concentrate the twist at the end of the wing. Placing the twist at the end of the wing will inhibit tip stalling and will also be a small step toward increased efficiency, as none of the lifting center portion of the 'wing will be twisted to a lower angle of attack.

Featured this month is a jig for cutting foam core wings. Of interest to tailless fans is the jig's ability to automatically cut the desired washout into the 'wing. Specifically, this jig is set up to begin the twist at the one half semi-span point; the root end wing half has no twist at all. The entire set up is adjustable to construction parameters.

Our jig was started with a base of flooring plywood. With a thickness of well over an inch, this three foot by eight foot base is heavy, but it is also very resistant to both bending and warping. All of the wooden strips are of 3/4 inch pine and are nailed in position.

We utilize aluminum roof flashing for template material, making a female template for the wing's lower surface and a male template for the upper. The templates are mounted one at a time between two pieces of pine stock fixed an appropriate distance apart. You will no doubt want some sort of locking mechanism to hold the templates in place in order to get consistent alignment. As these aluminum templates absorb heat from the cutting wire, be sure to mount the templates at least an inch away from the ends of the foam.

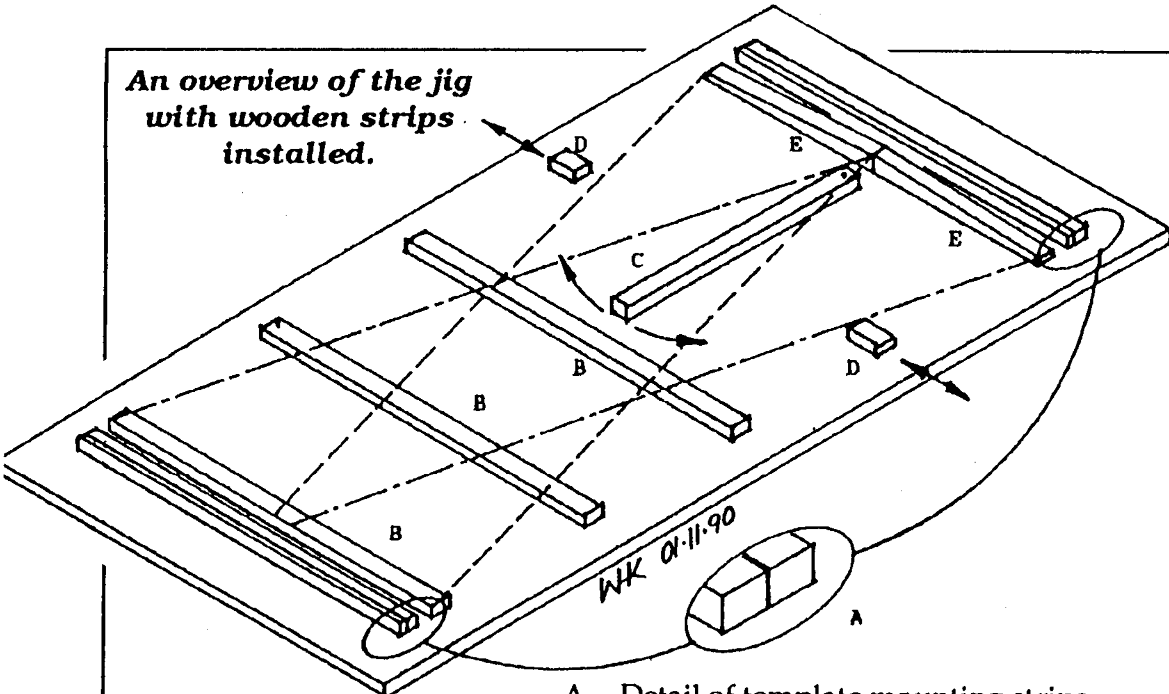
The root of the wing is always positioned at the left end of the jig, as shown in the drawing; the tip will always be at the right end, resting on the bevelled support strip. The bevel is set to the washout desired at the wing tip, but in the reversed direction. Note that after weighting down the foam block that the leading edge is straight, while the trailing edge is lower at the tips. After cutting, when you place the foam beds on a flat surface, the correct amount of washout (trailing edge up) will be automatically built in, along with the distribution of the twist across the span.

The drawing shows a movable leading edge brace (the swinging piece) and positionable trailing edge blocks. By varying their thickness and position, these TE blocks can control the rate of twist across this half of the semi-span. The left wing is outlined by the "dashed" line, the right by the "dash-dot-dash" line.

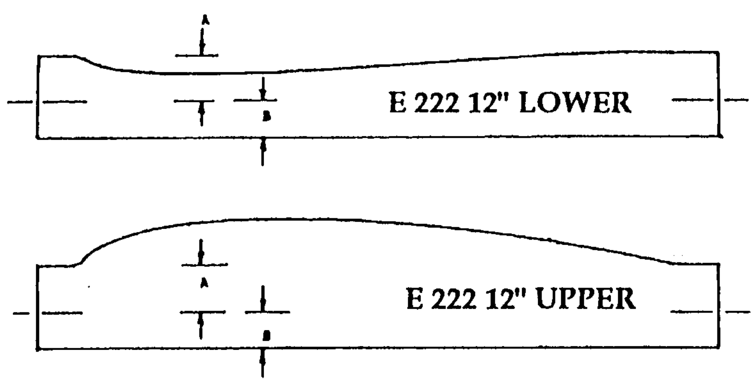
Our jig is easily adjusted. We just pull a few nails and tack the wooden strips in their new position(s). As we said before, the jig is heavy and is not easily moved. For this reason, some of you might want to try a good hollow core door as the base and use 3M "77" spray to "tack" the strips in position. An alternative that is a bit more sturdy would be to epoxy together a sandwich of two pieces of 1/4 inch plywood with one inch foam between, using a giant vacuum bag.

Like most of our projects, we cannot claim credit for much of this. First, the concept of twisting the foam before cutting, and "shelling" it while on a flat surface, is a simplified version of a process for creating elliptical wings of foam for use with F3D pylon racers. This was described in an RC Modeler article by Jaromir Bily. Second, the use of female and male templates is the recommendation of Bob Bayard of the South Bay Soaring Society in SBSS' Silent Flyer newsletter. Third, placing the twist near the tips, rather than across the entire span, came from the Hortens.

***An overview of the jig with wooden strips installed.***




A = Detail of template mounting strips.
B = Supports for root half of wing.
C = Movable leading edge support.
D = Trailing edge blocks.
E = Wing tip support. Note direction of slope!




These two diagrams show the female lower and male upper templates.
A = A distance usually equivalent to one half the foam's thickness.
B = The thickness of the supporting strips.

## "FASZINATION NURFLUGEL" REVIEW

"Faszination Nurflugel" is a new book on flying wings published by the German firm VTH (Verlag fur Technik und Handwerk GmbH). Hans-Jurgen Unverferth is the editor. Consisting of over 150 pages, it includes many photographs, drawings, 3-views and graphs. Divided into several sections, the book covers planks and swept wings, airfoils, control methods, and various solutions to problems pertinent to tailless aircraft. Additionally, several items dealing with flying wings and F3E (electro-flight) are included. Although the text is entirely in German, this is a valuable work. (A very simple German-English technical dictionary can assist immensely and we'll give you information on an inexpensive one at the end of this column.)

"Faszination Nurflugel" begins with a discussion of the evolution of flying wings, using Curt Weller's appearance at the 1982 Kaltenkirchner flying wing contest with his "Elfe II" as the starting point. This is followed by a brief definition of the term "Nurflugel" ("only wing").

The book really begins in earnest with a description of the plank concept. Included in this section are some airfoils which have sufficient stability for this type of tailless sailplane, some tips on wing geometry to improve efficiency, a simple method of computing the neutral point and CG, and various construction methods which can be used. Reinhard Werner, long a proponent of planks for thermal duration work, has written an entire article on flying techniques and design considerations for this type of glider.

Two members of the LOGO Team, Reinhard Kaufmann and Peter Wick, then explain the evolution of their team's attempts at achieving a competitive F3B 'wing. In all, descriptions for nine swept 'wings are included. Beginning with the "Gnom" in 1983/1984, and ending with the "Holon" in 1988, the entire process of integrating aerodynamics and increasingly sophisticated RC systems with piloting skills and iimproved performance can be traced. There are three views for five of the LOGO Team's aircraft.

Hans-Jurgen gives a wonderful description of his CEOZWO series, tracing its development from "Pirx," through "Just In Time," and then continuing with its evolution into a smaller version (CEOZWO-mini), a larger version (4 meters!), and a few electric powered versions. Hans-Jurgen also discusses some interesting construction methods. There are several 3-views in this chapter.

Flying wings nearly always fly well in a straight line. The problems arise when, as Reinhard Werner says, "... we stop letting them fly by themselves and begin stirring the sticks a little." Elevator, aileron, flaps and air brakes are all covered in a chapter written by Dr. Michael Wohlfart. His "six surface" system using one of the newer computer radios is marvelous!

Perhaps the most in-depth section is that dealing with winglets. Three 'wings are described; the first with no winglets, a second with large winglets covering nearly the entire tip of the wing, and a third which consists of a higher aspect ratio fin which covers the rear 50% of the wing tip. A number of graphs, fourteen in all, several pages of interpretation, and a summary table provide very good indication of performance characteristics for these configurations and allow the reader to relate the information to the objectives the designer wishes to obtain.

New airfoils - the MH 45, and EH 1.0/9.0, EH 1.5/9.0, and EH 2.0/10.0 - are described with polars, pressure distribution graphs, and coordinates. Zero lift angles and moment coefficients are given so the reader can reach conclusions regarding their application.

Contrary to the opinion held by many pilots of conventional aircraft, not all 'wings look the same. Horst Pritschow's "Octopus," a scythe-shaped 'wing, is shown and described through photos taken during construction, a good three-view and printed data, plus some in flight shots. A description of the underlying design philosophy makes for interesting reading. In the same section is a discussion of the implications of increasing the aspect ratio of a design. Sweep angle, wing twist, control methods, and construction techniques are all covered. Beginning with "Sky Diver" (aspect ratio of about 8.5) and ending with "Lotos" (aspect ratio of 20), Robert Schweissgut goes so far as to discuss the problems and implications of high speed stall at the wing tips during control surface deflection.

"Faszination Nurflugel" ends with a well written article by Prof. M. Schonherr. Here are described the seven basic problems of flying wings and how each is solved through the "Stromburg Principle." Control of air flow over the center section, for example, is obtained by a very specific method, and the results are demonstrated with actual in-flight photos of the tuft studies accomplished through use of an onboard camera mounted on the CG! The entire set-up is shown in one photo, and eight excellent pictures show controlled airflow during tow, turns, and a flaps down landing.

A short chapter describing currently available flying wing kits and another listing available literature back to 1984 finishes off the book. Other authors, who we failed to mention above, include Alfons Reiger, Martin Schlott, Curt Weller, and John Yost.

"Faszination Nurflugel" lacks some important items, like a method for calculating wing twist for various stability factors, but all of these missing things are readily available elsewhere. Hans-Jurgen's intent was to outline the progress of flying wing technology during the past several years, and to include "state-of-the-art" items along the way, while not duplicating the work of others. He has managed to do this in most outstanding fashion. "Faszination Nurflugel" is an excellent value and we recommend it highly.

"Faszination Nurflugel" is available directly from Verlag fur Technik und Handwerk GmbH.

Those of you who are looking for a reasonably priced German-English technical dictionary and finding only "big honkers" costing $60.00 and more, take heart. You will have a hard time bettering the RC sailplane terminology dictionary by Armin Saxer found in SOARTECH #6. It should already be on your library shelf, but if it's not, the complete 150+ page SOARTECH #6 is still available.

## KEN BATES' 'WINGS

"Nurflugelseglers tell no tales."

Lest we devote too many of our columns to European endeavors, particularly those going on in Germany, we've decided to trace the evolution of Ken Bates' thinking concerning tailless sailplanes by describing some of his designs.

Ken Bates' name is synonymous with tailless aircraft here in the United States. His notariety began with the "Windlord," a Standard Class (elevator and rudder, plus flaps) plank type sailplane which used the NACA 23009-75 airfoil. The "Windlord" won several contests, and a construction article for it appeared in the March 1978 issue of Model Aviation. With its relatively constant chord wing, radially ribbed wing tips, and "balsa block" fuselage, the "Windlord" was easily constructed. With its very light wing loading, the "Windlord" was an excellent soarer.

The "Manx" was also a plank, but of higher aspect ratio than the "Windlord." With a span of over 3.6 meters, it was definitely in the Unlimited Class. Ken used the NACA 23112 section with a modified camber line which had its crossover point at 75% chord. Some difficulties in maintaining the proper lower airfoil surface contour led to problems on early flights, yet once the solution was found, other problems began to arise. First, the nose had been built too long, so the moment of inertia got larger as weight was added to the tail in an effort to balance the airplane, and pitch authority suffered as a result. Second, the roll spoilers, used instead of ailerons, degraded performance each time they were used, and would not work at all when the ship was inverted. Finally, the "Manx" was destroyed during experiments to determine if it was sensitive to rearward tow hook location. (It was.)

Ken then began what turned out to be a several year excursion into swept wing designs, eventually achieving success.

Some early experiments with swept wings pointed to stability problems. Ken had started by using the same airfoils he had used on his planks, and he began to feel perhaps it was cross span flow which was hindering the reflexed sections' abilities to result in a stable platform. Additionally, Ken found the combination of wing flex and torsion (as described in "On the 'Wing...," RCSD 6/89) to be very difficult to control, and a long search for a method of building stiff, torsionally rigid wings ensued.

The "P" series of swept wings generated a lot of information regarding the behavior of this planform on tow, and methods of achieving coordinated turns and increasing thermalling ability. Tow problems occured because the winch did not feel the load of the 'wing, even when it was fully stalled. Ken's "P1" went through three variations, finally having a TD.051 engine installed; it proved to be both fast and aerobatic. "P2" was an exact scale Northrop N9M with a "simplex" symmetrical airfoil of 14% thickness. It had a bit better performance than the "P1." "P2" eventually was modified for electric power. Both "P1" and "P2" had spans of about 60 inches.

"P3" used a NACA 0012 section on a span of 104 inches, but it's biggest departure from its predecessors was its use of rotating wing tips for elevon control. Ken felt this would prevent tip stall on tow, even if full up was given, as the wing tips would be flying at a lower angle of attack than the main part of the wing. The first flight of "P3" was in April of 1982.

Low height on tow was a common problem of the "P" series, and the only visible hope was the use of a high speed winch which would catapult the 'wings into the air to a height matching their tailed competitors. Also in Ken's thoughts at this time was the use of undercambered rather than symmetrical sections. Ken felt once the tow problems were solved, 'wings could be very competitive in F3B and XC.

The "P3-B" featured a span of 125 inches, a root chord of 15 inches, and a tip chord of three inches. Control was once again by "tipalons." Tow problems had been reduced, a 60° initial climb angle was achieved, good stability and high airspeed were maintained, and height off tow was starting to get near that of a tailed sailplane. Due to susceptibility to damage, and flutter problems, Ken decided "tipalons" were not a good control method.

At this point Ken was looking for a competitive F3B 'wing design. "P4-A" and "P4-B" were styrofoam free flight models designed to test out potential airfoils. The "P4-A" used the Eppler 180 and turned out to be very stable and have a good glide angle. The "P4-B" used the Wortmann FX60-100 (undercambered) section and was very difficult to keep trimmed.

By 1986, Ken had flown the "P4-C." This 'wing used the Eppler 205. At the root the section was upright, at the tip it was inverted. By "stack sanding" the ribs, Ken was able to transition smoothly from one section to another. Forgetting about the aerodynamic washout caused by the inverted section, Ken put four degrees of geometric washout into the wing. The total aerodynamic washout then totaled about ten degrees; probably too much. Ken had difficulty turning the beast. For the first few flights, he would actually stall the glider, and then recover it headed in another direction! Adding to the turning problem was three degrees of dihedral per panel.

"After repairs," drag rudders were added. The ship now turned, but the glide suffered. Additionally, if the turn was made too tightly, the glide degraded into a spin. A number of consecutive problems while attempting to tow at high speed resulted in an equal number of crashes and eventual destruction of the "P4-C." A couple of lessons were learned, however: (1) Watch the washout and pay particular attention to the zero lift angles when doing the computing; and (2) Dihedral causes control difficulties in thermal turns, so reduce it to zero and use sweep if more yaw stability is needed.

Convinced yaw-roll coupling was the major cause of his swept 'wings' problems, Ken did some redesign work. When attempting to get good launch height, a 'wing must be able to withstand high launch speeds. The problem until this point had been that when the 'wing began climbing steeply it would also roll into the ground. Additionally, since Ken was looking for a contest airplane, he had to come up with a design which was inherently stable enough to not require high-tech stabilizing methods.

The design which eventually met these criteria was the "Keeper." "Keeper" had a two meter wingspan and used an Eppler 205 for the root section. The tip was also an E 205, modified to reflex form by Ken. Four degrees of twist were used, along with ten degrees of sweep. The big departure from previous ships was with the incorporation of anhedral. Anhedral cured the "yaw-roll" coupling problems of previous designs and allowed for zoom launches of such velocity the elevons would flutter. Even cross-wind launches proved not to be a problem.

"Keeper" had very good performance. It was able to thermal well, and it had 92% of the dead air time of the conventional tailed sailplane Ken tested it against, a two meter, E 205, flat winged Pilot "Harlequin" with ailerons.

By the end of 1986, Ken had built, flown and sold the "Sabre," a combination plank and swept wing using a slightly reflexed Eppler 205 and sporting a central fin. It flew well, but even with two large spars and thick balsa sheeting, flutter was still experienced when bringing the ship back upwind from a thermal. Not wanting to go to a foam core wing, Ken stuck with wood construction, but it seemed as though any increase in torsional strength brought on added weight which just couldn't be tolerated.

By the end of 1987, Ken had solved many of the problems which had plagued him from the beginning, and he had a new 'wing which towed and flew extremely well. The following points outline the improvements incorporated:

(1) The torsional rigidity of this new 'wing had been drastically improved with a new spar system. To give some idea as to this new spar's torsional rigidity, Ken recounted the following experience... During construction it was found the spar had been built with one degree too little twist; Ken tried to put the added degree of twist in while sheeting the wing and couldn't do it.

(2) No dihedral was used. Rather, the 'wing was built on a flat surface and there was a small amount of anhedral built in due to the tapered wing. The anhedral eliminated all of the yaw-roll coupling difficulties on tow, and no keel was needed.

(3) Elevons were placed in the outer third of the wing, for Ken found if they extend further inward there is increasing adverse yaw. Another advantage with this set up is no differential is needed.

(4) This model was not a pure flying wing, as it had tip fins. Quite often, when banking steeply, a true flying wing will slip in the direction of span and fall to the ground when flown at low speed. The tip fins on the new 'wing eliminated this behavior entirely.

(5) Ken added a "bat-tail" to the 'wing. This was accomplished by simply extending the root section with additional material so it followed the mean chord line of the airfoil. The trailing edge was then formed to produce a nice graceful curve leading from the center of the wing to the straight trailing edge. This smoothing of the quarter chord line very much improved the 'wing's thermaling ability.

(6) Sloppy linkages cannot be tolerated, so the servos were mounted in the wings with direct connections to the control surfaces.

At one of the MARCS Symposiums Ken said he at times "couldn't see the forest for the trees," and solutions to problems are obvious once discovered. A couple of things seem very clear to us, however; Ken learned from his experiences, whether they were successes or failures, and he has always shared with others what he has learned. In that regard, Ken Bates stands as a model for others to emulate. Unfortunately, we've not yet had the chance to meet Ken personally, but we are certainly eager for the opportunity!

The following table outlines the various sources of information used for this two part article:

| Model | White Sheet FW Special | SOARTECH | MARCS Symp. Proceedings | Misc. Sources |
|---|---|---|---|---|
| Windlord | FWS#1 (#7) | | 1985 | MA, 03/78 * |
| | | | | Werner, 1984 ** |
| | | | | Pers. corr. |
| Manx | FWS#1 (#7) | | 1985 | Werner, 1984 ** |
| P1-A, B, C | FWS#2 (#20) | #1 | | |
| P-2 | FWS#2 (#20) | #1 | | |
| P-3 | FWS#2 (#20) | #1 | 1985 | |
| P-3B | FWS#2 (#20) | #2 | | Pers. corr. |
| P-4A, 4B | FWS#2 (#20) | #2 | | |
| P-4C | FWS#3 (#36) | #4 & #7 | 1985 | |
| Keeper | | #7 | 1987 | |
| Sabre | | | 1987 | Pers. corr. |
| '87 'Wing | | | 1987 | |

* = Construction article with full size plans available from Model Aviation

** = "Nurflugelsegler Ferngesteuert" by Reinhard H. Werner

# REFLEXED AIRFOIL FORMULAE

New airfoils always seem so exciting! Most of us can barely contain the urge to get into the shop and build a whole airplane around a promising new section. What could be better than a method by which the modeler can create his own new airfoils? Well, for us "'wing nuts," how about a method of getting new airfoils for our tailless creations? To meet this challenge, we offer a small portion of an article written by Reinhard Werner. The entire article appeared in The White Sheet Radio Flying Club's "Flying Wings Special #3," Sean Walbank, Editor.

"Strictly speaking, it cannot be regarded as too profitable to use any home designed wing sections. If we really want to understand what's happening up there, as a matter of principle, we can't but use one of those wind tunnel tested airfoils, measure our model's performance parameters, and draw our conclusions from that. But unfortunately this would reduce our choice to just a handful of Eppler sections, and of course this seems to be quite a bit too restrictive. So just let's go on designing our own super sections, always remembering that two things seem desirable: low $C_m$ and good lift/drag ratio. Personally I'm not wholly happy with this procedure, but I won't entirely deny that good results may come of it. One thing's for sure: we're bound for adventure this way!

"Just one example for such home bred sections: Alex Lippisch gave us a mean camber line with a slight reflex and the crossover point at 87.5% chord. This line was not stable and required quite a bit of sweep and/or twist. Now if we modify this camber line a little, it looks like this:

$$y = \frac{f}{94350} \cdot x \cdot (x - 100) \cdot (x - 75),$$

with x running from 0 to 100, f = % camber.

(We note the denominator, 94350, can be changed to 94500 with the resulting camber line peaking at exactly the correct value. The 94350 value produces a camber line which is a bit too high. -$B^2$)

"This line has its crossover point at 75% and should be dead stable. It looks interesting, too, with the crossover at 80%:

$$y = \frac{f}{105000} \cdot x \cdot (x - 100) \cdot (x - 80).$$

"Now just add a thickness distribution *a la* NACA, Quabeck, Kaczanowski or whatever, and you've got a weird looking section. And, well, there's still the Horten camber line:

$$y = \frac{f}{10546875} \cdot x \cdot (100 - x)^3.$$

"So just have a try out there - I'd be delighted to hear of the results!"

This whole concept sounded so intriguing to us that we wrote a computer program to figure out the three camber lines for us. Then we gathered up some thickness distributions we felt might be appropriate for use. The result is an on-screen display of any chosen thickness distribution superimposed over the reflexed meanline with the % camber of our choice. This program, written in Apple's Applesoft BASIC, can be easily modified for use with other graphics-capable computers.

## WERNER REFLEXED SECTIONS

```
100   D$ =  CHR$ (4):TWO = 2: DIM X(30): DIM T(30): DIM
      YU(2,30): DIM YL(2,30): DIM Y75(30): DIM Y80(30): DIM
      H(30):X = 0:Y = 1: DIM C(60,1)
200   TEXT : HOME
300   PRINT "What is the designation of the airfoil  that you
      wish computed?  ";: INPUT A$
301   REM  READ X-AXIS INCREMENTS
302   PRINT D$;"OPEN";A$;".XT"
303   PRINT D$;"READ";A$;".XT"
304   FOR I = 0 TO 30
305   INPUT X(I)
306   INPUT T(I)
307   IF X(I) = 100 AND T(I) = 0 THEN A = I:I = 30
308   NEXT I
310   PRINT D$;"CLOSE";A$;".XT"
320   PRINT : PRINT "And what % thickness?  ";: INPUT PT$
330   PT =  VAL (PT$)
331   P1 = PT / 10
332   IF PT < 10 THEN PT$ = "0" + PT$
333   PT$ = "-" + PT$
338   PRINT : PRINT "What % camber?  ";: INPUT F
1350  REM 75%
1360  HGR : HCOLOR= 3
1400  FOR I = 0 TO A
1500  Y75(I) = F * X(I) * (X(I) - 100) * (X(I) - 75) / 94350
1525  NEXT I
1540  HPLOT X(0) * TWO,50 TO X(A) * TWO,50
1550  HPLOT X(0) * TWO,50 - Y75(0) * TWO
1600  FOR I = 1 TO A
1700  HPLOT  TO X(I) * TWO,50 - Y75(I) * TWO
1800  NEXT I
1900  FOR I = 0 TO A
2000  YU(0,I) = (Y75(I) + T(I) * P1)
2050  HPLOT X(I) * TWO,50 - YU(0,I) * TWO
2100  YL(0,I) = (Y75(I) - T(I) * P1)
2150  HPLOT X(I) * TWO,50 - YL(0,I) * TWO
2200  NEXT I
2250  REM 80%
2300  FOR I = 0 TO A
2400  Y80(I) = F * X(I) * (X(I) - 100) * (X(I) - 80) / 105000
2425  NEXT I
2440  HPLOT X(0) * TWO,100 TO X(A) * TWO,100
2450  HPLOT X(0) * TWO,100 - Y80(0) * TWO
2500  FOR I = 1 TO A
2600  HPLOT  TO X(I) * TWO,100 - Y80(I) * TWO
2700  NEXT I
2800  FOR I = 0 TO A
2900  YU(1,I) = (Y80(I) + T(I) * P1)
2950  HPLOT X(I) * TWO,100 - YU(1,I) * TWO
3000  YL(1,I) = (Y80(I) - T(I) * P1)
```

```
3050  HPLOT X(I) * TWO,100 - YL(1,I) * TWO
3100  NEXT I
3101  REM HORTEN
3102  FOR I = 0 TO A
3103  H(I) = F * X(I) * ((100 - X(I)) ^ 3) / 10546875
3104  NEXT I
3105  HPLOT X(0) * TWO,150 TO X(A) * TWO,150
3106  HPLOT X(0) * TWO,150 - H(0) * TWO
3107  FOR I = 1 TO A
3108  HPLOT  TO X(I) * TWO,150 - H(I) * TWO
3109  NEXT I
3110  FOR I = 0 TO A
3111  YU(2,I) = (H(I) + T(I) * P1)
3112  HPLOT X(I) * TWO,150 - YU(2,I) * TWO
3113  YL(2,I) = (H(I) - T(I) * P1)
3114  HPLOT X(I) * TWO,150 - YL(2,I) * TWO
3115  NEXT I
3150  VTAB (21): PRINT A$;", reflex at 75% - top
3160  PRINT A$;", reflex at 80% - middle"
3165  PRINT A$;", Horten line   - bottom"
3170  PRINT "Any key to continue  ";
3200  GET W$
5100  TEXT : HOME
5200  PRINT "Save coordinates to disc?"
5210  PRINT "      1.  75% only"
5220  PRINT "      2.  80% only"
5225  PRINT "      3.  Horten only"
5230  PRINT "      4.  75% and 80%"
5231  PRINT "      5.  75% and Horten"
5232  PRINT "      6.  80% and Horten"
5233  PRINT "      7.  All three"
5240  PRINT "      8.  None"
5245  PRINT
5250  GET W: PRINT W
5260  IF W = 1 THEN  GOSUB 6000: GOTO 8000
5270  IF W = 2 THEN  GOSUB 7000: GOTO 8000
5280  IF W = 3 THEN  GOSUB 7600: GOTO 8000
5290  IF W = 4 THEN  GOSUB 6000: GOSUB 7000: GOTO 8000
5292  IF W = 5 THEN  GOSUB 6000: GOSUB 7600: GOTO 8000
5294  IF W = 6 THEN  GOSUB 7000: GOSUB 7600: GOTO 8000
5296  IF W = 7 THEN  GOSUB 6000: GOSUB 7000: GOSUB 7600:
      GOTO 8000
5298  IF W = 8 THEN  GOTO 8000
5300  GOTO 5100
6000  REM  75%
6100  FOR I = 0 TO A
6200  C(I,X) = X(A - I)
6300  C(I,Y) = YU(0,A - I)
6400  NEXT I
6410  FOR I = A + 1 TO 2 * A
6420  C(I,X) = X(I - A)
6430  C(I,Y) = YL(0,I - A)
6440  NEXT I
6500  IF PT$ = "-10" THEN PT$ = ""
```

```
6501  PRINT D$"OPEN";A$;PT$;"-75/";F
6510  PRINT D$"DELETE";A$;PT$;"-75/";F
6520  PRINT D$"OPEN";A$;PT$;"-75/";F
6530  PRINT D$"WRITE";A$;PT$;"-75/";F
6540  FOR I = 0 TO 2 * A
6550  PRINT C(I,X): PRINT C(I,Y)
6560  NEXT I
6570  PRINT D$"CLOSE";A$;PT$;"-75/";F
6999  RETURN
7000  REM 80%
7100  FOR I = 0 TO A
7200  C(I,X) = X(A - I)
7300  C(I,Y) = YU(1,A - I)
7400  NEXT I
7410  FOR I = A + 1 TO 2 * A
7420  C(I,X) = X(I - A)
7430  C(I,Y) = YL(1,I - A)
7440  NEXT I
7500  IF PT$ = "-10" THEN PT$ = ""
7501  PRINT D$"OPEN";A$;PT$;"-80/";F
7510  PRINT D$"DELETE";A$;PT$;"-80/";F
7520  PRINT D$"OPEN";A$;PT$;"-80/";F
7530  PRINT D$"WRITE";A$;PT$;"-80/";F
7540  FOR I = 0 TO 2 * A
7550  PRINT C(I,X): PRINT C(I,Y)
7560  NEXT I
7570  PRINT D$"CLOSE";A$;PT$;"-80/";F
7599  RETURN
7600  REM   HORTEN
7610  FOR I = 0 TO A
7620  C(I,X) = X(A - I)
7630  C(I,Y) = YU(2,A - I)
7640  NEXT I
7650  FOR I = A + 1 TO 2 * A
7660  C(I,X) = X(I - A)
7670  C(I,Y) = YL(2,I - A)
7680  NEXT I
7690  IF PT$ = "-10" THEN PT$ = ""
7700  PRINT D$"OPEN";A$;PT$;"-H/";F
7710  PRINT D$"DELETE";A$;PT$;"-H/";F
7720  PRINT D$"OPEN";A$;PT$;"-H/";F
7730  PRINT D$"WRITE";A$;PT$;"-H/";F
7740  FOR I = 0 TO 2 * A
7750  PRINT C(I,X): PRINT C(I,Y)
7760  NEXT I
7770  PRINT D$"CLOSE";A$;PT$;"-H/";F
7999  RETURN
8000  REM AGAIN?
8100  TEXT : HOME
8200  PRINT "Do you wish to compute another?"
8250  PRINT
8300  PRINT "  1.  Different camber or thickness,           same
      airfoil"
8400  PRINT "  2.  Different airfoil"
```

```
8500   PRINT "  3.  End"
8600   PRINT : GET W: PRINT W
8700   IF W = 1 THEN  TEXT : HOME : GOTO 320
8710   IF W = 2 THEN  GOTO 200
8720   IF W = 3 THEN  END
8730   GOTO 8100
```

## THICKNESS DATA

```
10     DIM X(60): DIM T(60)
20     D$ =  CHR$ (4)
40     TEXT : HOME
50     PRINT "This program will accept input thick-   ness
       contour coordinates and save the   resulting matrix on
       disc"
60     PRINT : PRINT "Follow the prompts...";
70     GET W$: PRINT W$
80     TEXT : HOME
120    PRINT "What profile designation?  ";: INPUT F$
125    PRINT : PRINT : PRINT "Start with the leading edge
       (X = 0, T = 0) and end with the trailing edge (X = 100,
       T = 0).  This is very          important, as the program
       will not work properly otherwise."
150    PRINT : PRINT
170    FOR A = 0 TO 60
180    IF A < 10 THEN  PRINT " ";
190    PRINT A;" X: ";: INPUT X(A)
200    IF A < 10 THEN  PRINT " ";
210    PRINT A;" T: ";: INPUT T(A)
220    PRINT : PRINT "Are these coordinates correct? ";: GET W$:
       PRINT W$: IF W$ <  > "Y" AND W$ <  > "N" THEN  HOME :
       GOTO 220
230    IF W$ = "N" THEN  HOME : GOTO 180
250    PRINT : IF X(A) = 100 AND T(A) = 0 THEN B = A:A = 60
260    NEXT A
280    REM  CHECK
290    TEXT : HOME
300    FOR A = 0 TO B
310    IF A < 10 THEN  PRINT " ";
320    PRINT A;" X: ";X(A);: HTAB (15): PRINT " T: ";T(A)
330    IF A = 0 GOTO 350
340    IF A / 10 =  INT (A / 10) THEN  GET W$: PRINT W$: HOME
350    NEXT A
370    PRINT : PRINT "Were all of the above correct? ";: GET W$:
       PRINT W$: IF W$ <  > "Y" AND W$ <  > "N" THEN  GOTO 370
380    IF W$ = "Y" GOTO 560
390    PRINT
400    PRINT "Which coordinate(s) were wrong?"
410    PRINT "List them as prompted..."
420    PRINT : PRINT "# = ";: INPUT N
430    PRINT "X or T? ";: GET I$
440    IF I$ <  > "X" AND I$ <  > "T" THEN  GOTO 430
```

```
450   IF I$ = "X" THEN  PRINT "This is currently ";X(N)
460   IF I$ = "T" THEN  PRINT "This is currently ";T(N)
480   PRINT "Correction needed? ";: GET W$: PRINT W$: IF W$
      <  > "Y" AND W$ <  > "N" THEN  GOTO 480
490   IF W$ = "Y" THEN  GOTO 510
500   GOTO 520
510   PRINT : PRINT "Input the correct number : ";: INPUT C
512   IF I$ = "X" THEN X(N) = C
514   IF I$ = "T" THEN T(N) = C
520   PRINT : PRINT "Another correction? ";: GET W$: PRINT W$:
      IF W$ <  > "Y" AND W$ <  > "N" THEN  GOTO 520
530   IF W$ = "Y" THEN  GOTO 420
540   REM ALL CHECKED OK
550   GOTO 290
560   HOME
570   PRINT "The designation of this airfoil is"
575   PRINT F$: PRINT
580   PRINT "(.XT will be added to the file name       as it is
      SAVEd.)": PRINT
590   PRINT "Write to disc? ";: GET W$: PRINT W$: IF W$ <  >
      "Y" AND W$ <  > "N" THEN  GOTO 560
600   IF W$ = "N" THEN  GOTO 1000
610   HOME : PRINT "Writing to disc... "
620   PRINT D$"OPEN";F$;".XT"
630   PRINT D$"DELETE";F$;".XT"
640   PRINT D$"OPEN";F$;".XT"
650   PRINT D$"WRITE";F$;".XT"
660   FOR A = 0 TO B
670   PRINT X(A): PRINT T(A)
680   NEXT A
690   PRINT D$"CLOSE";F$;".XT"
700   HOME
710   PRINT "Another set of coordinates? ";: GET W$: IF W$ <  >
      "Y" AND W$ <  > "N" THEN  GOTO 700
720   IF W$ = "Y" THEN  CLEAR : GOTO 10
730   HOME : END
1000  PRINT : PRINT "Do you wish to change the designation   of
      the profile?  Pressing <N> will abortand allow you to
      restart at the          beginning."
1010  GET W$: PRINT W$
1020  IF W$ <  > "Y" AND W$ <  > "N" THEN  HOME : GOTO 1000
1030  IF W$ = "N" THEN  GOTO 700
1040  HOME : PRINT "New designation?": INPUT F$: GOTO 560
```

NACA 63-010

| X | Y |
|---|---|
| 0.0 | 0.000 |
| .5 | 0.829 |
| .75 | 1.004 |
| 1.25 | 1.275 |
| 2.5 | 1.756 |
| 5 | 2.440 |
| 7.5 | 2.950 |
| 10 | 3.362 |
| 15 | 3.994 |
| 20 | 4.445 |
| 25 | 4.753 |
| 30 | 4.938 |
| 35 | 5.000 |
| 40 | 4.938 |
| 50 | 4.496 |
| 60 | 3.715 |
| 70 | 2.712 |
| 80 | 1.618 |
| 85 | 1.088 |
| 90 | 0.604 |
| 95 | 0.214 |
| 100 | 0.000 |

NACA 63A-010

| X | Y |
|---|---|
| 0.0 | 0.000 |
| .5 | 0.816 |
| .75 | 0.983 |
| 1.25 | 1.250 |
| 2.5 | 1.737 |
| 5 | 2.412 |
| 7.5 | 2.917 |
| 10 | 3.324 |
| 15 | 3.950 |
| 20 | 4.400 |
| 25 | 4.714 |
| 30 | 4.913 |
| 35 | 4.995 |
| 40 | 4.968 |
| 50 | 4.613 |
| 60 | 3.943 |
| 70 | 3.044 |
| 80 | 2.040 |
| 90 | 1.030 |
| 95 | 0.525 |
| 100 | 0.021 |

**NACA 64-010**

| X | Y |
|---|---|
| 0.0 | 0.000 |
| 0.5 | 0.820 |
| 0.75 | 0.989 |
| 1.25 | 1.250 |
| 2.5 | 1.701 |
| 5 | 2.343 |
| 7.5 | 2.826 |
| 10 | 3.221 |
| 15 | 3.842 |
| 20 | 4.302 |
| 25 | 4.639 |
| 30 | 4.864 |
| 35 | 4.980 |
| 40 | 4.988 |
| 50 | 4.586 |
| 60 | 3.820 |
| 70 | 2.827 |
| 80 | 1.722 |
| 90 | 0.671 |
| 95 | 0.248 |
| 100 | 0.000 |

**NACA 64A-010**

| X | Y |
|---|---|
| 0.0 | 0.000 |
| 0.5 | 0.804 |
| 0.75 | 0.969 |
| 1.25 | 1.225 |
| 2.5 | 1.688 |
| 5 | 2.327 |
| 7.5 | 2.905 |
| 10 | 3.199 |
| 15 | 3.813 |
| 20 | 4.272 |
| 25 | 4.606 |
| 30 | 4.837 |
| 35 | 4.968 |
| 40 | 4.995 |
| 45 | 4.894 |
| 50 | 4.684 |
| 55 | 4.388 |
| 60 | 4.021 |
| 70 | 3.127 |
| 80 | 2.103 |
| 85 | 1.582 |
| 90 | 1.062 |
| 95 | 0.541 |
| 100 | 0.021 |

NACA 65A-010

| X | Y |
|---|---|
| 0.0 | 0.0 |
| 0.5 | 0.765 |
| 0.75 | 0.928 |
| 1.25 | 1.183 |
| 2.5 | 1.623 |
| 5 | 2.182 |
| 7.5 | 2.650 |
| 10 | 3.040 |
| 15 | 3.658 |
| 20 | 4.127 |
| 25 | 4.483 |
| 30 | 4.742 |
| 35 | 4.912 |
| 40 | 4.995 |
| 45 | 4.983 |
| 50 | 4.863 |
| 55 | 4.632 |
| 60 | 4.304 |
| 65 | 3.899 |
| 70 | 3.432 |
| 75 | 2.912 |
| 80 | 2.352 |
| 85 | 1.771 |
| 90 | 1.188 |
| 95 | 0.604 |
| 100 | 0.021 |

NACA 65-010

| X | Y |
|---|---|
| 0.0 | 0.000 |
| .5 | 0.772 |
| .75 | 0.932 |
| 1.25 | 1.169 |
| 2.5 | 1.574 |
| 5 | 2.177 |
| 7.5 | 2.647 |
| 10 | 3.040 |
| 15 | 3.666 |
| 20 | 4.143 |
| 25 | 4.503 |
| 30 | 4.760 |
| 35 | 4.924 |
| 40 | 4.996 |
| 45 | 4.963 |
| 50 | 4.812 |
| 55 | 4.530 |
| 60 | 4.146 |
| 65 | 3.682 |
| 70 | 3.156 |
| 75 | 2.584 |
| 80 | 1.987 |
| 85 | 1.385 |
| 90 | 0.810 |
| 95 | 0.306 |
| 100 | 0.000 |

NACA 0010

| X | Y |
|---|---|
| 0.0 | 0.0000 |
| .75 | 1.2374 |
| 1.25 | 1.5782 |
| 2.5 | 2.1789 |
| 5 | 2.9622 |
| 7.5 | 3.4999 |
| 10 | 3.9023 |
| 12.5 | 4.2128 |
| 15 | 4.4543 |
| 20 | 4.7813 |
| 25 | 4.9510 |
| 30 | 5.0014 |
| 35 | 4.9572 |
| 40 | 4.8358 |
| 45 | 4.6506 |
| 50 | 4.4117 |
| 55 | 4.1270 |
| 60 | 3.8028 |
| 65 | 3.4437 |
| 70 | 3.0533 |
| 75 | 2.6336 |
| 80 | 2.1859 |
| 82.5 | 1.9517 |
| 85 | 1.7105 |
| 87.5 | 1.4621 |
| 90 | 1.2064 |
| 92.5 | 0.9432 |
| 95 | 0.6721 |
| 97.5 | 0.3929 |
| 98.75 | 0.2500 |
| 100 | 0.0000 |

**ELINA**

| X | X |
|---|---|
| 0.00 | 0.000 |
| 1.25 | 1.345 |
| 2.5 | 1.925 |
| 5 | 2.71 |
| 7.5 | 3.285 |
| 10 | 3.72 |
| 15 | 4.36 |
| 20 | 4.73 |
| 25 | 4.92 |
| 30 | 4.95 |
| 40 | 4.67 |
| 50 | 4.15 |
| 60 | 3.49 |
| 70 | 2.73 |
| 80 | 1.88 |
| 90 | 1.05 |
| 95 | 0.61 |
| 100 | 0.14 |

**HQ-0/10**

| X | Y |
|---|---|
| 0.0 | 0.000 |
| .5 | 0.722 |
| 1.25 | 1.278 |
| 2.5 | 1.889 |
| 5 | 2.667 |
| 10 | 3.556 |
| 15 | 4.222 |
| 20 | 4.556 |
| 25 | 4.778 |
| 30 | 4.889 |
| 35 | 5.000 |
| 40 | 4.833 |
| 50 | 4.556 |
| 60 | 3.778 |
| 70 | 2.778 |
| 80 | 1.722 |
| 85 | 1.167 |
| 90 | 0.778 |
| 95 | 0.333 |
| 100 | 0.000 |

**SAFTIG**

| X | Y |
|---|---|
| 0.00 | 0.000 |
| 1.25 | 1.188 |
| 2.5 | 1.750 |
| 5 | 2.563 |
| 7.5 | 3.125 |
| 10 | 3.563 |
| 15 | 4.188 |
| 20 | 4.625 |
| 30 | 5.000 |
| 40 | 4.813 |
| 50 | 4.375 |
| 60 | 3.750 |
| 70 | 2.875 |
| 80 | 2.063 |
| 90 | 1.063 |
| 95 | 0.500 |
| 100 | 0.063 |

**MARTIN**

| X | Y |
|---|---|
| 0 | 0 |
| 1.25 | 1.363 |
| 2.5 | 1.704 |
| 5 | 2.159 |
| 7.5 | 2.613 |
| 10 | 3.068 |
| 15 | 3.772 |
| 20 | 4.318 |
| 30 | 5 |
| 40 | 4.772 |
| 50 | 4.545 |
| 60 | 3.863 |
| 70 | 3.068 |
| 80 | 2.272 |
| 90 | 1.25 |
| 95 | 0.681 |
| 100 | 0 |

RG 12A

| X | Y |
|---|---|
| 0.0000 | 0.0000 |
| 0.2271 | 0.5299 |
| 0.8443 | 1.0784 |
| 2.0069 | 1.7251 |
| 3.5494 | 2.3201 |
| 5.5311 | 2.8810 |
| 7.9224 | 3.3883 |
| 10.7121 | 3.8352 |
| 13.8781 | 4.2145 |
| 17.3980 | 4.5214 |
| 21.2444 | 4.7532 |
| 25.3866 | 4.9086 |
| 29.7905 | 4.9881 |
| 34.4171 | 4.9933 |
| 39.2246 | 4.9271 |
| 44.1676 | 4.7929 |
| 49.1979 | 4.5951 |
| 54.2661 | 4.3373 |
| 59.3208 | 4.0227 |
| 64.3139 | 3.6467 |
| 69.1807 | 3.2065 |
| 73.8474 | 2.7302 |
| 78.2717 | 2.2558 |
| 82.4097 | 1.8050 |
| 86.2125 | 1.3925 |
| 89.6336 | 1.0291 |
| 92.6268 | 0.7208 |
| 95.1461 | 0.4661 |
| 97.1705 | 0.2565 |
| 98.6926 | 0.1016 |
| 99.6628 | 0.0206 |
| 100.0000 | 0.0000 |

RG 14A

| X | Y |
|---|---|
| 0.0000 | 0.0000 |
| 0.2366 | 0.5565 |
| 0.8755 | 1.1442 |
| 2.0312 | 1.8072 |
| 3.5648 | 2.4158 |
| 5.5341 | 2.9834 |
| 7.9103 | 3.4907 |
| 10.6869 | 3.9317 |
| 13.8421 | 4.3001 |
| 17.3531 | 4.5921 |
| 21.1921 | 4.8058 |
| 25.3279 | 4.9404 |
| 29.7262 | 4.9979 |
| 34.3477 | 4.9807 |
| 39.1514 | 4.8932 |
| 44.0909 | 4.7403 |
| 49.1185 | 4.5282 |
| 54.1830 | 4.2632 |
| 59.2331 | 3.9519 |
| 64.2138 | 3.6011 |
| 69.0747 | 3.2153 |
| 73.7630 | 2.7906 |
| 78.2110 | 2.3366 |
| 82.3647 | 1.8859 |
| 86.1805 | 1.4653 |
| 89.6125 | 1.0887 |
| 92.6159 | 0.7657 |
| 95.1456 | 0.4959 |
| 97.1776 | 0.2728 |
| 98.7002 | 0.1078 |
| 99.6657 | 0.0218 |
| 100.0000 | 0.0000 |

RG 15A

| X | Y |
|---|---|
| 0.0000 | 0.0000 |
| 0.3049 | 0.6203 |
| 1.1040 | 1.2661 |
| 2.2646 | 1.8706 |
| 3.8801 | 2.4693 |
| 5.8987 | 3.0163 |
| 8.3313 | 3.5123 |
| 11.1535 | 3.9442 |
| 14.3469 | 4.3071 |
| 17.8876 | 4.5956 |
| 21.7489 | 4.8075 |
| 25.8995 | 4.9414 |
| 30.3054 | 4.9982 |
| 34.9280 | 4.9791 |
| 39.7260 | 4.8875 |
| 44.6543 | 4.7256 |
| 49.6654 | 4.4978 |
| 54.7148 | 4.2026 |
| 59.7459 | 3.8348 |
| 64.6897 | 3.4110 |
| 69.4954 | 2.9611 |
| 74.1168 | 2.5074 |
| 78.5038 | 2.0665 |
| 82.6063 | 1.6519 |
| 86.3751 | 1.2749 |
| 89.7635 | 0.9428 |
| 92.7258 | 0.6611 |
| 95.2171 | 0.4280 |
| 97.2166 | 0.2359 |
| 98.7164 | 0.0935 |
| 99.6695 | 0.0190 |
| 100.0000 | 0.0000 |

# MISCELLANEOUS TOPICS

## NEW EPPLER 230 DATA

An important item mentioned by Dr. Walter Panknin in his MARCS Symposium presentation dealt with the Eppler 230 airfoil. Frequently used on swept 'wings as the tip airfoil, it is a reflexed section which many builders have relied on to provide stability without requiring large amounts of twist. Walter's experience and research, however, showed the Eppler 230 may not be capable of a large stabilizing effect after all, and the actual pitching moment is roughly half of the published value: +0.025. This is of great importance to those who are designing and constructing swept 'wings, and individuals with computer programs using E 230 data files should update their information to reflect this more accurate value.

## NEW AIRFOILS

In an effort to extract increases in performance from tailless sailplanes, the Swiss Logo Team has been experimenting with some new airfoils. We have now used one of these new airfoils and can report excellent performance along with good stability. The sections have very low positive pitching moments and are well suited to foam/fiberglass/vacuum bag construction. We'll publish a full report, complete with coordinates, soon!

## THE ICAROSAUR FLYING WING

In a recent telephone conversation with Gene Dees, he reports having sold the rights to the Icarosaur to a manufacturer of RPVs (Remotely Piloted Vehicles... That's military talk for RC reconnaissance aircraft), effectively eliminating any possibility of full sized plans being available. Gene is, however, working on an article for Flying Models magazine which will describe the Icarosaur in such detail anyone interested in constructing one can do so. Watch for it!

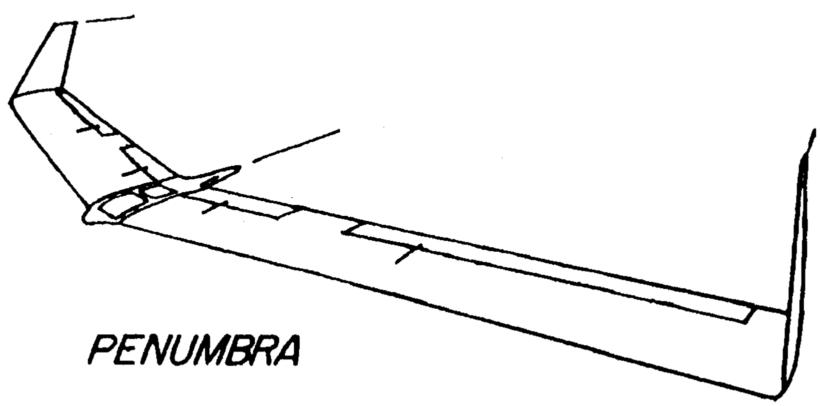
Herk Stokely, soaring columnist for Flying Models, has been featuring tailless aircraft in the last few issues!

## TAILLESS BIBLIOGRAPHY AVAILABLE

We recently acquired a very well written "Tailless Bibliography" authored by Serge Krauss. Although dealing primarily with full sized aircraft, the bibliography has many references of use to modelers. Citation dates range from well before 1900 to the present. We thoroughly enjoyed Serge's comments in the introduction regarding various tailless designs and their designers! Although complete as it stands, Serge has plans to continue expanding the work and is looking for contributions. Copies may be obtained directly from Serge Krauss.

## PROJECT PENUMBRA

Our own long term project, an F3B/Thermal Duration swept 'wing, has undergone considerable progress lately. After nearly five years of sketches, improvements, and procrastination we can at last report a qualified success! We'd delayed construction because it seemed we always acquired a piece of information which changed a major component each time we were ready to start. We finally decided to start constructing something, as otherwise we would never get anything into the air. We are convinced the resulting aerodynamic design is fairly optimized, but structurally we still have a way to go. Watch for updates!



PENUMBRA

## DR. WALTER PANKNIN AT THE MARCS SYMPOSIUM

The first part of November, 1989, saw us in Madison, Wisconsin, for the Madison Area Radio Control Society's National Sailplane Symposium. MARCS '89 enjoyed a very large number of attendees, and all of the speakers were superb. Of particular interest to flying wing enthusiasts was the presentation given by Dr. Walter Panknin, the originator of the "Flying Rainbow" series of flying wing sailplanes. This month's column will be devoted to a synopsis of Walter's presentation, "Flying Rainbows; Basics, Building and Beauty of Flying Wings."

Walter began his talk with some slides - a short history of the origins of the Flying Rainbows, followed by photos of his 'wings in the air. "Magnificent" is the only word to describe them. Other photos showed some of the experimental configurations Walter has tried, plus some good closeups of present design features. One outstanding characteristic of Walter's 'wings is the pattern of their brilliant colors - truly "Flying Rainbows"!

The more technical portion of Walter's talk began with an explanation of the similarity between conventional tailed aircraft and flying wings: that is, the flying wing does have a horizontal stabilizer - it is at the wing tips! The same stabilizing loads produced by the tail of a conventional aircraft are also produced by the ends of the wings for a tailless aircraft. Once this idea becomes a part of your thinking, everything to be known about flying wing pitch stability becomes quite obvious.

Walter gave the "magic formula" for wing twist. This computation involves such things as the aspect ratio, moment coefficients of the airfoils used, taper ratio, and stability factor. The end result is the geometric twist needed for stability. He then led the symposium participants through an example which made everything clear.

As a general recommendation, use the Eppler 222 at the root and the Eppler 230 at the tip. A wing root chord of 14 inches should give enough room for the receiver and a large battery pack (1200mah). A span of 110 to 140 inches and a tip chord of 9 inches gives a lot of wing area. The geometric twist used is determined by the "magic formula." Control of pitch and roll is by elevons which extend over the outer one third of the semispan, while speed range is expanded by use of spoilers or flaps. Servos must be put into the wings themselves so they are directly linked to the control surfaces. Construction should be of foam with balsa skins to provide a strong, stiff structure which will have excellent performance. This excellent performance was demonstrated by both mathematical modeling and results of actual flight testing against conventional tailed aircraft.

Of special interest to us were Walter's ideas concerning winglets. While not needed for flight, they are recommended as aids to visibility. As Walter so aptly said, "Out of sight, still in mind, comes the crash!"

The harmonic oscillations which can occur during high wing load maneuvers were also mentioned. Walter's solution involves maintaining a relatively large root chord.

Walter's presentation concluded with the five steps to success: (1) understand what you do; (2) build it stiff, not only strong; (3) no play in the linkages; (4) precise location of the CG; and (5) have confidence it will fly. He then issued a challenge to the symposium attendees: "Would you try it?"

A complete transcript of Dr. Panknin's presenation, along with all of the pertinent drawings, are available within the <u>Proceedings</u> of the 1989 MARCS Symposium.

If you have access to a Commodore 64 computer and Simon's BASIC, you may be interested in obtaining a copy of Walter's Flying Rainbow computer program which can assist you in designing your own flying wings. Contact Lee Murray, LJM Associates, for more information.

## AN UPDATE ON PROJECT PENUMBRA

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, (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 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 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 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 plank designs would not be competitive in the F3B environment as they tend to be one speed airplanes. We also knew 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 thermaling 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 $1^{\circ}$ 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 we've never gone to the time, trouble, and expense of putting the finishing coat of epoxy on it. We also realized 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 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 which would work well.

The 1989 MARCS Symposium featured Dr. Walter Panknin talking about his "Flying Rainbows." Dr. Panknin was quite effective at committing us to our concept. Home from Madison we immediately set up our vacuum bagging system. We laid out 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 flights of Penumbra.1 were hand launches over wet grass on a cold morning. Several hand tosses indicated 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 the 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 upon the line with no veering and came off the line with no problems. Turns were made in both directions. There was absolute silence during an overhead pass. Two 360° 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, we discovered the upper surface of both wings had failed in compression! This probably occurred during the single winch launch. It suddenly dawned on us fiberglass is not so good in compression as balsa, and Walter's spar system was for a balsa sheeted wing. We were pleased, however, Penumbra.1 had not only continued to fly but had flown so well, even with major structural failure.

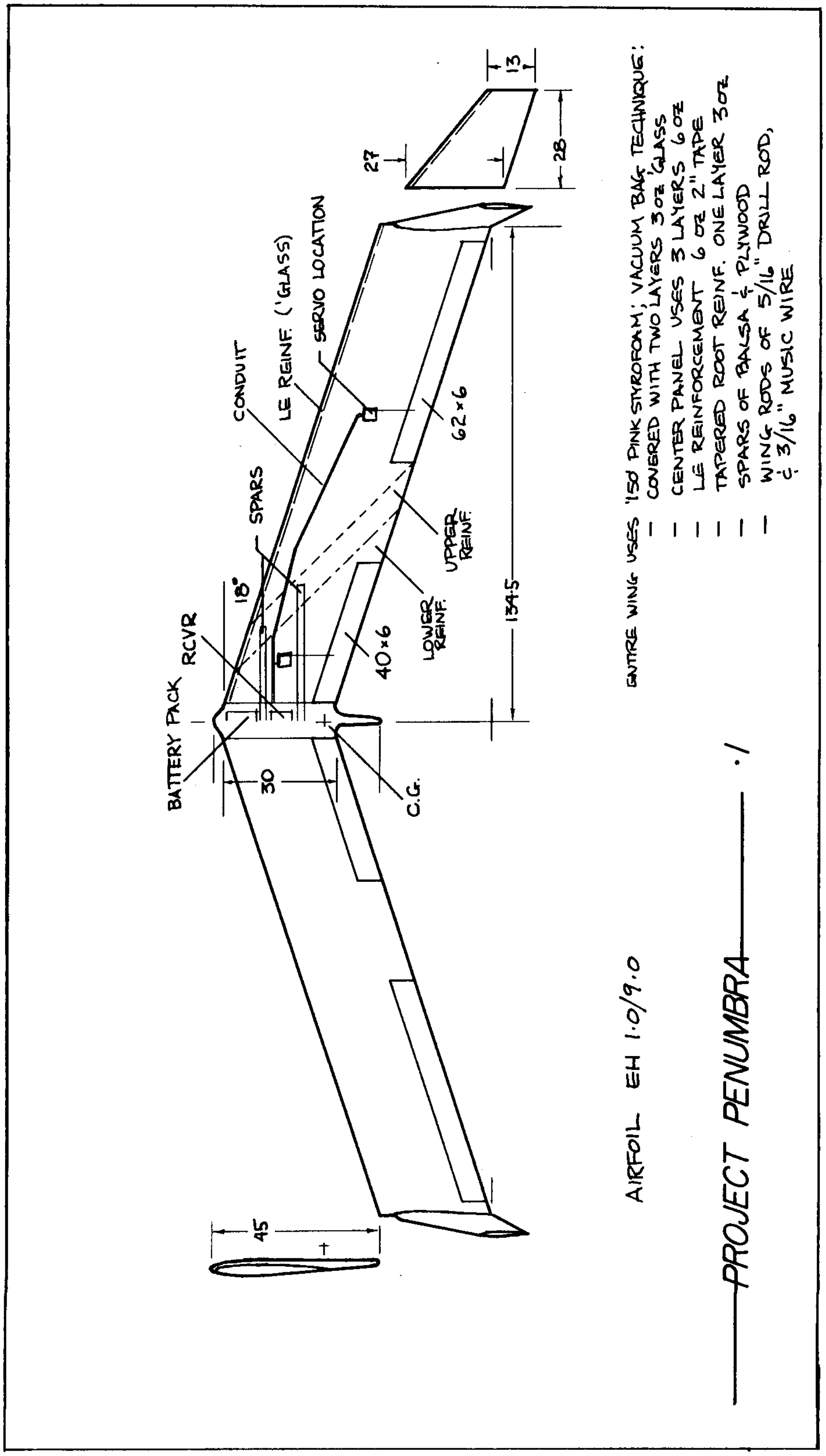
Constructed of pink foam and fiberglass, Penumbra.2 is aerodynamically identical to Penumbra.1; structurally, two 3/32" plywood vertical web spars in each wing reach well past the previous point of failure. Penumbra.2 has now been completed and winch launched several times.

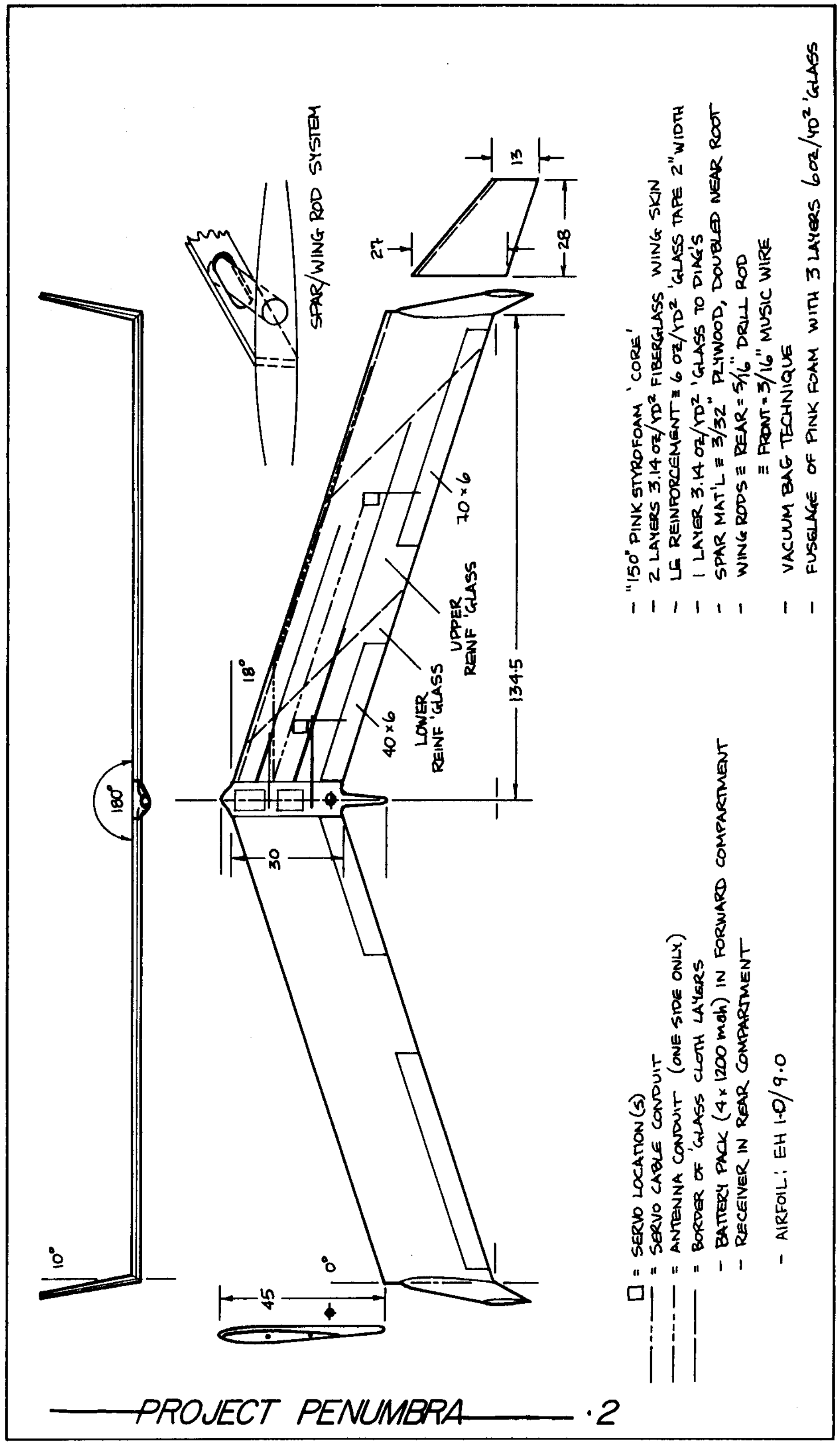
Results of these first flights have been quite satisfying. Air speed is very high, but Penumbra.2 gives obvious indications when in lift, and has been thermaled. Although a bit pitch sensitive, aileron control is quite positive, and the flaps, when deflected 80°, bring her to a nearly complete stop. 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. Our construction techniques have been challenged, but the project falls well within our capabilities. Penumbra.1 proved easier to fly than expected, and demonstrated the great potential of the planform. Penumbra.2 has confirmed these notions. 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 competition machine, they do include information on materials used in both versions and show the points of failure on Penumbra.1.


BATTERY PACK
RCVR
18°
SPARS
CONDUIT
LE REINF. ('GLASS)
SERVO LOCATION
62×6
UPPER REINF.
LOWER REINF.
40×6
30
C.G.
134.5
27
28
13
45
AIRFOIL EH 1.0/9.0
ENTIRE WING USES '150 PINK STYROFOAM; VACUUM BAG TECHNIQUE;
– COVERED WITH TWO LAYERS 3 OZ 'GLASS
– CENTER PANEL USES 3 LAYERS 6 OZ
– LE REINFORCEMENT 6 OZ 2" TAPE
– TAPERED ROOT REINF. ONE LAYER 3 OZ
– SPARS OF BALSA & PLYWOOD
– WING RODS OF 5/16" DRILL ROD, & 3/16" MUSIC WIRE
PROJECT PENUMBRA
.1


SPAR/WING ROD SYSTEM
13
27
28
70 × 6
UPPER REINF 'GLASS
LOWER REINF 'GLASS
40 × 6
134.5
18°
180°
30
10°
0°
45
- "150" PINK STYROFOAM 'CORE'
- 2 LAYERS 3.14 OZ/YD² FIBERGLASS WING SKIN
- LE REINFORCEMENT = 6 OZ/YD² 'GLASS TAPE 2" WIDTH
- 1 LAYER 3.14 OZ/YD² 'GLASS TO DIAG'S
- SPAR MAT'L = 3/32" PLYWOOD, DOUBLED NEAR ROOT
- WING RODS = REAR = 5/16" DRILL ROD
= FRONT = 3/16" MUSIC WIRE
- VACUUM BAG TECHNIQUE
- FUSELAGE OF PINK FOAM WITH 3 LAYERS 6 OZ/YD² 'GLASS
□ = SERVO LOCATION (S)
= SERVO CABLE CONDUIT
= ANTENNA CONDUIT (ONE SIDE ONLY)
= BORDER OF 'GLASS CLOTH LAYERS
- BATTERY PACK (4 × 1200 mah) IN FORWARD COMPARTMENT
- RECEIVER IN REAR COMPARTMENT
- AIRFOIL: EH 1.0/9.0
PROJECT PENUMBRA ·2

## THE EH SERIES OF AIRFOILS

Three new airfoils this month, all for swept 'wings, and all designed by John Yost. The EH 1.0/9.0 is for F3B, the EH 1.5/9.0 for F3E and thermal duration, and the EH 2.0/10.0 for situations requiring more stable, higher lift 'wings. These sections are for use on constant chord wings of moderate sweepback, about 20°. Very little twist is needed due to their slightly positive pitching moments. All are capable of very high performance when used with the proper airframe.

EH 1.0/9.0

| X | Yu |
|---|---|
| 100.0000 | 0.0000 |
| 99.6057 | 0.0150 |
| 99.1144 | 0.0412 |
| 98.4292 | 0.0870 |
| 97.5528 | 0.1533 |
| 96.4888 | 0.2385 |
| 95.2414 | 0.3411 |
| 93.8153 | 0.4606 |
| 92.2164 | 0.5974 |
| 90.4508 | 0.7522 |
| 88.5257 | 0.9252 |
| 86.4484 | 1.1162 |
| 84.2274 | 1.3243 |
| 81.8712 | 1.5482 |
| 79.3893 | 1.7866 |
| 76.7913 | 2.0379 |
| 74.0877 | 2.3002 |
| 71.2890 | 2.5715 |
| 68.4062 | 2.8493 |
| 65.4508 | 3.1310 |
| 62.4345 | 3.4136 |
| 59.3691 | 3.6938 |
| 56.2667 | 3.9680 |
| 53.1395 | 4.2324 |
| 50.0000 | 4.4828 |
| 46.8605 | 4.7149 |
| 43.7333 | 4.9242 |
| 40.6309 | 5.1063 |
| 37.5655 | 5.2568 |
| 34.5492 | 5.3716 |
| 31.5938 | 5.4669 |
| 28.7110 | 5.4791 |
| 25.9123 | 5.4655 |
| 23.2087 | 5.4041 |
| 20.6107 | 5.2936 |
| 18.1288 | 5.1338 |
| 15.7726 | 4.9255 |
| 13.5516 | 4.6708 |
| 11.4743 | 4.3724 |
| 9.5492 | 4.0341 |
| 7.7836 | 3.6606 |
| 6.1847 | 3.2578 |
| 4.7586 | 2.8317 |
| 3.5112 | 2.3893 |
| 2.4472 | 1.9387 |
| 1.5708 | 1.4910 |
| 0.8856 | 1.0617 |
| 0.3943 | 0.6667 |
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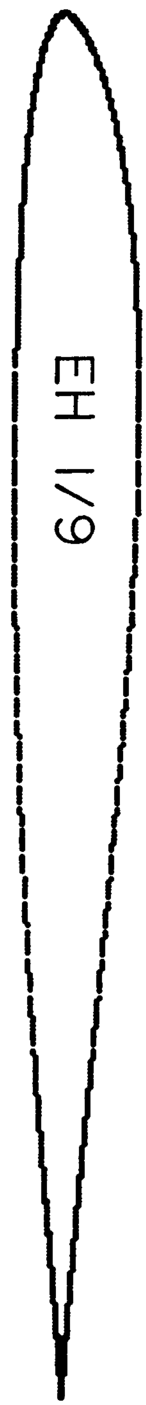


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| 2.4472 | -1.5094 |
| 3.5112 | -1.7932 |
| 4.7586 | -2.0548 |
| 6.1847 | -2.2927 |
| 7.7836 | -2.5071 |
| 9.5492 | -2.6985 |
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| 13.5516 | -3.0159 |
| 15.7726 | -3.1439 |
| 18.1288 | -3.2530 |
| 20.6107 | -3.3439 |
| 23.2087 | -3.4171 |
| 25.9123 | -3.4730 |
| 28.7110 | -3.5120 |
| 31.5938 | -3.5340 |
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ZLA = $-0.37^{o}$
Cmo = 0.00088
Thickness = 8.99%

EH1.5/9.0

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| 93.8153 | 0.4636 |
| 92.2164 | 0.6015 |
| 90.4508 | 0.7579 |
| 88.5257 | 0.9335 |
| 86.4484 | 1.1283 |
| 84.2274 | 1.3418 |
| 81.8712 | 1.5731 |
| 79.3893 | 1.8213 |
| 76.7913 | 2.0851 |
| 74.0877 | 2.3630 |
| 71.2890 | 2.6531 |
| 68.4062 | 2.9532 |
| 65.4508 | 3.2604 |
| 62.4345 | 3.5718 |
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| 56.2667 | 4.1923 |
| 53.1395 | 4.4927 |
| 50.0000 | 4.7800 |
| 46.8605 | 5.0490 |
| 43.7333 | 5.2941 |
| 40.6309 | 5.5097 |
| 37.5655 | 5.6905 |
| 34.5492 | 5.8310 |
| 31.5938 | 5.9263 |
| 28.7110 | 5.9720 |
| 25.9123 | 5.9647 |
| 23.2087 | 5.9018 |
| 20.6107 | 5.7819 |
| 18.1288 | 5.6048 |
| 15.7726 | 5.3717 |
| 13.5516 | 5.0852 |
| 11.4743 | 4.7492 |
| 9.5492 | 4.3686 |
| 7.7836 | 3.9496 |
| 6.1847 | 3.4996 |
| 4.7586 | 3.0265 |
| 3.5112 | 2.5388 |
| 2.4472 | 2.0461 |
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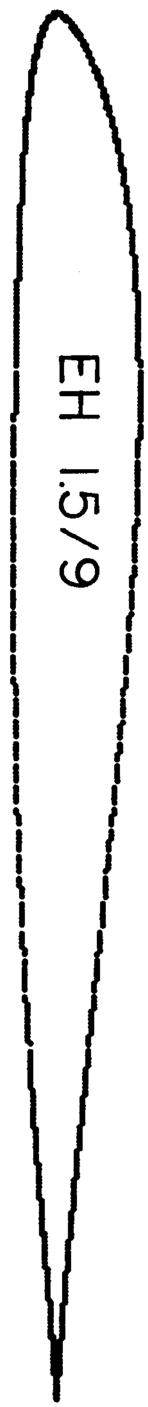


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| 86.4484 | -1.0678 |
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ZLA = $-0.55^{o}$
Cmo = 0.00073
Thickness = 9.0%

EH 2.0/10.0

| X | Yu |
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| 99.6057 | 0.0201 |
| 99.1144 | 0.0512 |
| 98.4292 | 0.1034 |
| 97.5528 | 0.1776 |
| 96.4888 | 0.2732 |
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| 93.8153 | 0.5226 |
| 92.2164 | 0.6769 |
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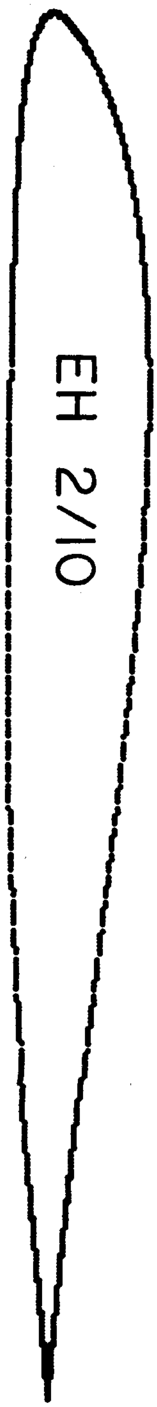


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| 99.6057 | -0.0201 |
| 99.9013 | -0.0048 |
| 100.0000 | 0.0000 |

ZLA = $-0.74^{\circ}$
Cmo = 0.00165
Thickness = 10.07%

## LOBO - NEW (FLYING WING) KIT IN TOWN

The Lobo is a new flying wing kit being put out by Steve Steidl of Albuquerque, New Mexico. Designed for slope flying in winds up to 30mph, the Lobo spans 71 inches and has 638 $in^2$ of wing area for a wing loading of under 8 $oz/ft^2$.

This 'wing has been designed with a generous canopy and separated elevator and aileron function. This allows use of a standard size no frills two channel system with no mixing required! This definitely makes the kit less intimidating and more accessible to the average modeler. If you have a radio with mixing capability you can make some minor modifications and install elevons if you wish.

Steve reports the Lobo to be very stable in all three axes, and it should therefore make an excellent 'ship for the intermediate pilot seeking out a first flying wing. Steve has handed his transmitter to flyers with no flying wing experience and found they have no problems and require no assistance at all. On the other hand, the Lobo is capable of just about any aerobatics asked of it with the exception of inverted flight and good axial rolls. (Those two minor faults are side effects of its great stability.)

The Lobo kit is easy to build and comes with everything you need except hinge tape! If you're interested in obtaining a kit or more information, contact Steve directly.

## SUGGESTIONS FOR FIRST 'WINGS - PART I

We've been writing this column for over two years now, and have received an immense amount of mail. Each and every letter received has been answered, and we've enjoyed the whole process tremendously. Many ideas for this column have been derived from readers' questions, and we wish to thank everyone for their positive comments and ideas. Your interest and enthusiasm is very much appreciated.

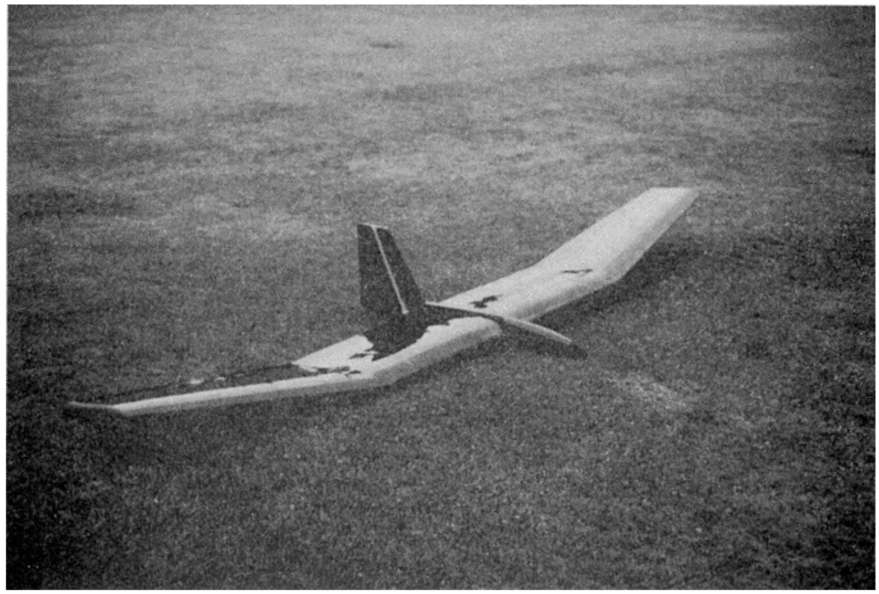
While many readers have written asking for airfoil data, computer programs, and current sources of flying wing information (hopefully in English rather than German), the most frequent request is for our suggestions regarding a first tailless sailplane.

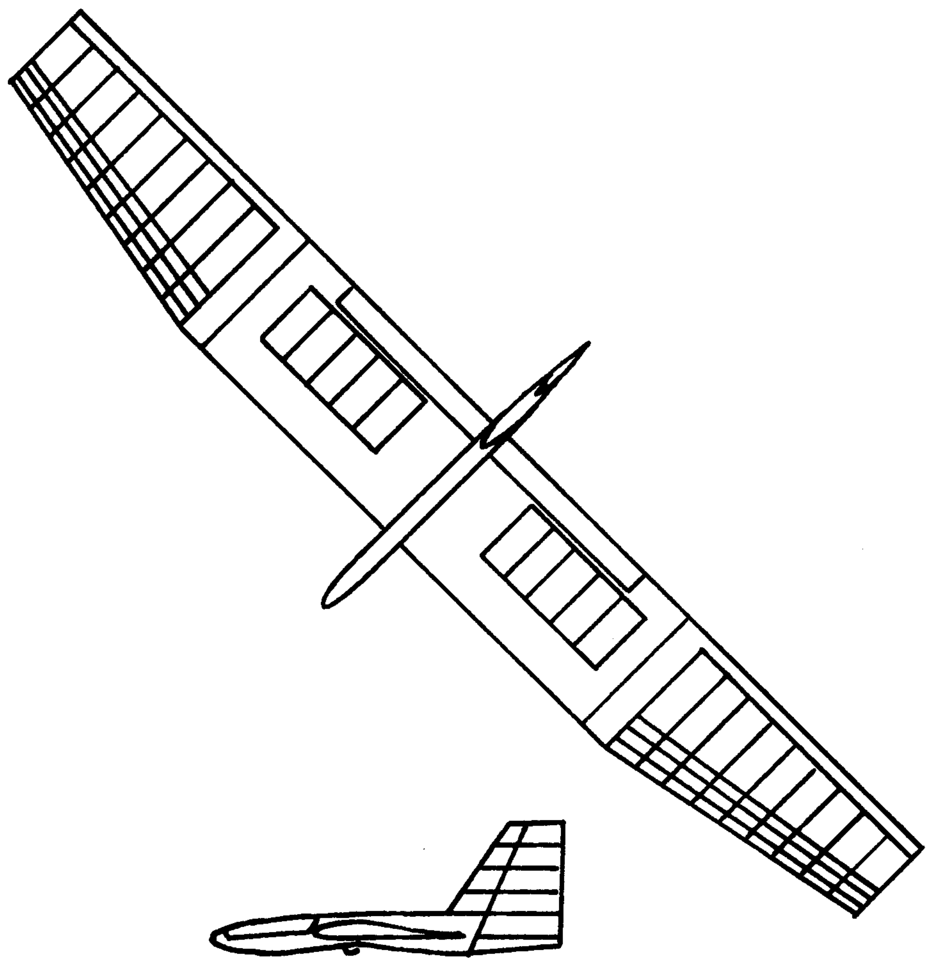
Those who want to try a tailless sailplane have various motives. Some want a glider which is easily built, fun to fly, and a bit different than what's normally seen at the flying field. Others want to start construction of a flock of 'wings for competition because they believe this is the best method of achieving a particular set of goals. One fellow wrote and said his intention was to go through the whole League of Silent Flight program using only tailless designs! Since the majority have built kits and feel confident a scratch built 'wing will not pose a difficulty, we normally suggest one of two gliders which are available as full sized plans. The main determining factor in making our recommendation is the experience of the builder. If the individual has been building, flying, and enjoying rudder and elevator type gliders, then we suggest Dave Jones' Raven. If the writer has experience with aileron sailplanes, then we recommend Dave's Blackbird 2M. This month we'll discuss the Raven; a description of the Blackbird 2M will follow next month.

The Raven is a plank design which comes in several versions. There's a Mini-Raven of 78" span at the smaller end of the scale, and a Raven-Super with a 124" span at the larger end. Our choice is the Raven version published in Model Builder magazine some years ago. It has a span of 110" and a very nice streamlined fuselage. The Model Builder Raven fuselage provides a snug fit for a 500mah battery pack, receiver, and the two standard size servos. Control is by rudder and central elevator. The wing is in three sections, with the center section being permanently attached to the fuselage. This means the two servos in the fuselage can always remain connected to their respective control surfaces. The outer wing panels include the dihedral breaks and are of very light construction so turns are not inhibited by unnecessary inertia. Construction is of balsa, plywood, and spruce; there are no exotic materials used. Neither of the two Ravens that we've built have required significant nose weight to achieve the proper CG location. The plans show an easy ballast tube installation.

We built our two Ravens by following the plans and directions exactly. Although neither has flaps, we recommend the necessary modifications. Use of flaps will allow higher launches and lower landing speeds. Due to the size of the fuselage, the flap servo will most likely need to go in the wing center section. As mentioned above, the center section is permanently attached to the fuselage, so there will be no need to disconnect any of the flap mechanism when disassembling the Raven after a flying session. The flaps themselves should be about 5% of the total wing area, be mounted on the lower surface of the wing with their leading edge at 40% of the local chord, and be capable of 40 degree deflection. Flaps should not be used while thermalling, as to do so markedly reduces performance.

The Raven is a very stable sailplane which we've found will automatically center in a thermal. A few years ago, at a Northwest Soaring Society Tournament in Richland, we launched, flew out, and thermalled for over five minutes while moving the controls only enough to make sure the radio gear was still working. Later we realized our options would have been severely limited had the radio gear not been working, and the flight would have perhaps been even better had we gone ahead and let her fly without any control input at





all until it was necessary to bring her down to land.

Last year we found the above described realization to be more than completely accurate when, during a winch launch, the receiver battery pack shorted out. The Raven went up on tow without a waver, floated off, went into a nice gentle left turn, and did a picture perfect landing directly next to the winch several minutes later. That experience served to confirm our belief that the Raven makes a great trainer. The performance certainly awed the spectators!

Our first Raven, affectionately called Lenore, is covered with black Monokote on the top and metallic charcoal on the bottom. Our second, Encore, built a short time later, is all white Monokote. Both have a chrome band around the right wing outboard of the dihedral break. We learned to fly proportional with Lenore, and both have had their share of collisions with soccer goal posts and landings in trees. But after more than six years they retain the majority of their original covering, and structural repairs have always been easily accomplished.

If we were to build another Raven, we would again choose the *Model Builder* version. We'd add flaps and use the CJ-25209 section rather than the CJ-3309 shown on the plans. The CJ-25209, the newer section of the two, has a bit better penetration capability with no noticeable loss of lift. Since both have large flat areas on their bottom surface, there is no change in construction method or completion time.

## SUGGESTIONS FOR FIRST 'WINGS - PART II

Last month we suggested Dave Jones' Raven for those used to flying sailplanes with rudder and elevator. This month we'll cover Dave's Blackbird 2M, our suggestion for a first 'wing for those flyers with aileron experience.

The Blackbird 2M, as the name implies, is a two meter tailless sailplane. It bears only a slight resemblence to other "plank" designs as it has a lower aspect ratio (about 5:1), and a sleek fin but no rudder. Control is by elevons. Performance is noticeably better than the Raven's; it is also faster than the Raven, and does extremely well on the slope as well as in thermals.

The Blackbird 2M can be built with detachable wings, or as a one piece airframe. Detachable wings make transportation easier, and some builders may want to add ballast tubes in the wing roots during construction. A one piece airframe means less overall weight, but the addition of ballast may be kind of tricky. Overall airframe strength for the two versions should be about equal.

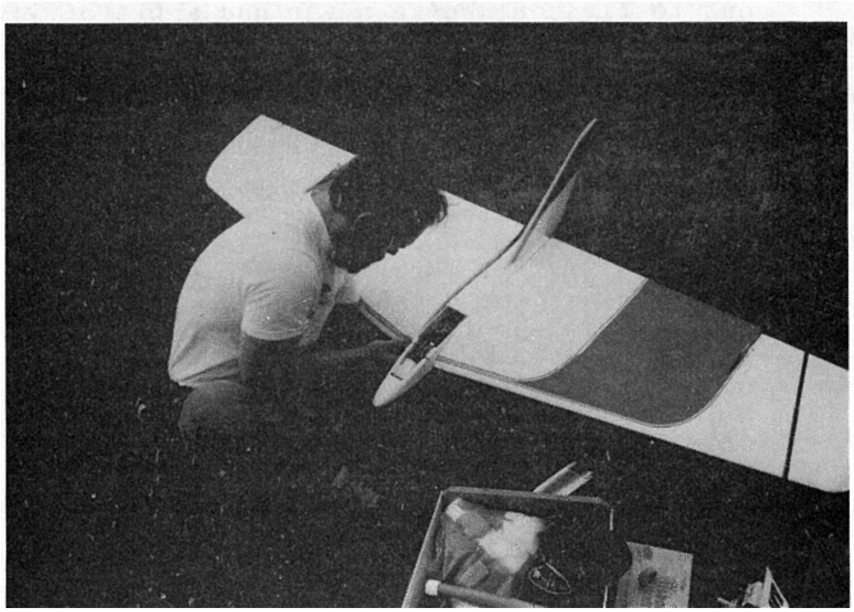
Like the Raven plans, these show the CJ-3309 airfoil. Our recommendation, followed by at least two other builders, has been to use the CJ-25209 instead. This provides better penetration qualities with no loss of thermaling performance. Construction is not affected as both airfoils have flat bottoms and there is no twist built into the wings.

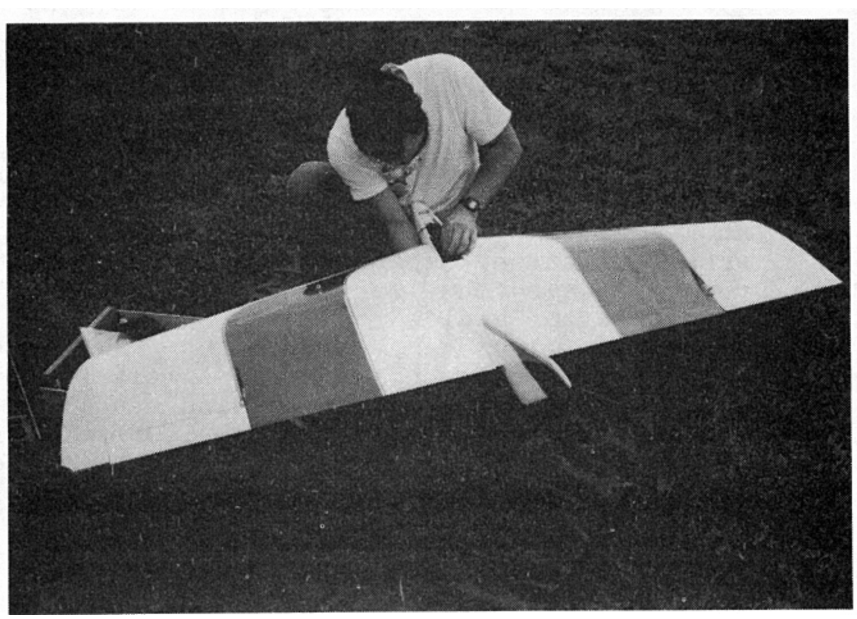
For best performance, the elevon servos should be placed in the wings with direct connections to the control surfaces. This means running cables through conduits, but with the servos moved out to the inner edge of the elevons the fuselage becomes rather cavernous. We placed an antenna tube right behind the leading edge of the wing. Linkage adjustments are a breeze with this configuration, and all of the play resulting from snaked push-pull cables is eliminated. Our Blackbird XC has its standard size servos in its wings, while our two meter, built before we knew better, has its two micro servos in the fuselage. We've intended to move them for some time but have not yet done so, and we curse ourselves each time we go out to fly her. We've never had a bit of problem with glitches caused by the antenna being close to the servo leads. (JR Century VII, FM PPM system)

The most astounding part of flying the Blackbird 2M is the zoom at the end of tow, and in general the stiffer the breeze the higher the zoom. We enlarged the width of the spars to 3/4" at the root, but left their thickness as noted on the plans. The wing rods are as specified. We consistently launch this two meter version without pulsing the winch at all, and the zoom can double the height achieved. We could probably get even more height if we installed flaps on the beast! We're not sure an unmodified spar system could take these sorts of loads. What's so impressive about the Blackbird 2M is the fact it uses no exotic materials; balsa, plywood, and spruce make up the entire airframe.

Our Blackbird 2M, which we've called Candide ever since her first flight, is still going strong after more than five years. Why the name Candide? Because that first flight was also our first ever with an aileron equipped sailplane. (We were flying our Ravens exclusively until then.) It was at a Northwest Soaring Society contest in Burlington, Washington, and took place after a single hand toss over tall grass. Actually, she was trimmed out perfectly but the pilot wasn't up to her capabilities. Those of you who have heard the late Leonard Bernstein's "Overture to Candide" have the idea.

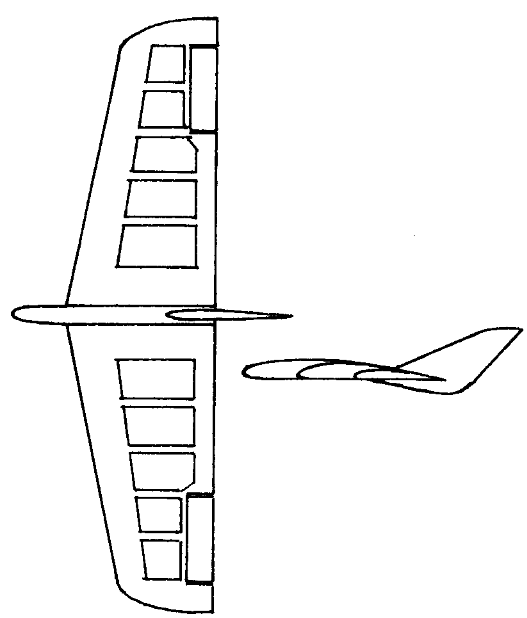
We fly in a county park which is relatively long and narrow. Luckily the wind usually comes out of the right direction. One of our favorite flight patterns is to launch to the west, then fly east and downwind over the roadway and trees at the north boundary of the field. Sometimes we get some lift from the line of trees, sometimes from the road. We keep travelling east until we're past the eastern border of the park and well over a quarter mile away. Visibility, even at that distance, has not been a problem. After





circling the trees, parking lots and road at the east end of the field for a while, we most likely will get impatient and a bit carried away by the capabilities of the Blackbird 2M and head her back toward us, traveling west again. Our usual goal is to apply just enough down elevator for Candide to come directly back, always in the same spot in the sky, about 30 degrees above the horizon, but getting larger all the time. The gain in speed is fantastic, and we thoroughly enjoy peeling off at the last moment and watching her swoosh past and go into a graceful climbing arc while bleeding off airspeed. There is very little noise, and what there is most likely comes from the finger holes under the wing roots.

As those who have built the Blackbird 2M can attest, its performance is very good and it's extremely maneuverable. In as few words as possible, it's a real kick to fly. At the risk of being branded heretics, we'd like to see someone build an electric version!



# FLAPS AND AIR BRAKES FOR VARIOUS TAILLESS DESIGNS

There has always been some resistance to using flaps on tailless designs. Why this is so has always puzzled us, as there are any number of flying wings, both full sized and model, which incorporate them. The YB-49 and its predecessor, the XB-35, both utilized flaps to lower landing speeds. The B-2, the "Stealth Bomber," has full camber changing capability through use of flaps controlled by a triple redundant computer system. In the model realm, Gene Dees' Icarosaur pioneered the use of flaps and used the system to great advantage.

Since questions concerning guidelines for size, location, and use of flaps (and air brakes, too) are common, this month's column endeavors to provide the answers.

## Flaps on plank designs

It is important to realize a plank design obtains its stability from the reflexed rear portion of the wing, and so any sort of air disturbance over that part of the wing will no doubt influence the stability of the aircraft in some way. (More about this later, when we talk about air brakes.) For now, keep in mind a flap placed on the bottom of a reflexed wing will decrease the stability of the wing because the airflow over the lower part of the reflexed section is disturbed. The majority of the stability provided by that portion of the wing will be derived from the airflow over the upper surface alone.

If you are looking to put flaps on a plank design, keep these guidelines in mind: (1) the flap area needs to be only about 5% of the total wing area, (2) the flaps should be mounted as close as possible to the 40% chord point, as this will reduce any pitching tendency to a minimum, (3) flap deflection needs to be only about 40°, as they are very effective, and (4) it is best if the flaps can be kept away from the control surfaces which influence pitch.

Flaps can be used on launch to get a steeper climb, and the effect is significant. Another use, of course, is to slow the 'wing for landing. Flaps should NOT be used when thermalling! Also, you may need to remember to retract them just before touchdown to prevent stripping the servo gears.

## Flaps for swept 'wings

Flaps on swept 'wings are used just as they are on conventional tailed aircraft, and their effects are identical. Flaps can be used to significantly improve launches and slow the 'wing substantialy for landing. Depending on the airfoil(s) used, flaps may be used to advantage in various flight regimes as well.

In looking at a number of swept 'wings with flaps, we find the following similarities: (1) the flaps usually cover about one third of the wingspan, starting at the wing to fuselage junction, (2) the flap chord is about 20% of the wing chord.

In practice we've found flap deflections of about $20^{o}$ to be very effective during launch. (But make sure they are retracted for the zoom!) Deflections of 75 to 80 degrees or more can be used for landing, and this really slows the 'wing down. As with conventional tailed sailplanes, lowering the flaps has the tendency to pitch the nose up, so some form of elevator compensation is needed. Also, as with their use on planks, you may need to retract the flaps just before touchdown.

## Some miscellaneous notes on flaps

If your plank's design has a centrally located elevator, the elevator servo can be mounted in the fuselage along with the rudder servo. A torque tube system to drive the flaps would need only a single additional fuselage mounted servo. On the other hand, outboard elevons should be driven directly by wing mounted servos. Flaps on a swept 'wing are best driven by separate wing mounted servos as well. We have long argued for the mounting of all wing control surface servos in the wings themselves, if possible and advantageous.

As we mentioned above, lowering the flaps on a swept 'wing will cause the nose to pitch up, and some form of compensation will be needed. The new computerized radios are great for mixing channels and making fine adjustments.

## Air brakes

Planks, with their lack of sweepback, lend themselves well to air brake installation. An air brake consists of two blades which push up and out of the wing when deployed; one from the upper surface, one from the lower surface. For a plank type 'wing, the blades must rise clear of the wing surface so air can flow relatively freely over both the upper and lower surface of the reflexed trailing edge. For a two meter 'wing, a set of 250 mm air brakes is grossly oversized - better to use a 100mm size, if you can find them. Air brakes are, as their name implies, a method for increasing drag and not for increasing lift. Their usefulness, therefore, is limited.

We have seen only one swept 'wing with air brakes, probably due to the difficulties involved. If the air brakes are mounted parallel to the quarter chord line a large vortex forms at the trailing end, but if mounted at $90^{o}$ to the centerline they take on the arched quality of the airfoil's upper surface. There are no good solutions to the problems of incorporating them into this planform, and it seems flaps are a far better choice in this application.

* * *

There you have it, the basics of flaps and air brakes on tailless sailplanes! While some experimentation may be necessary, the benefits to be derived from their use are well worth the effort.

# ALAN HALLECK'S RAZER1
and
# DR. PANKNIN'S TWIST FORMULAE

This month we describe a computer program to help design swept 'wings, and the result of Alan Halleck's use of the program - his RAZER1 slope racer!

Our trip to the 1989 MARCS Symposium was a wonderful experience, and we wrote about Dr. Walter Panknin's presentation on flying wings, "Flying Rainbows," in the September 1990 issue of RCSD. As we mentioned in that report, Walter gave out a packet of materials to those interested in designing their own flying wings. Included were the formulae for determing wing twist based on required $C_L$ and a stability factor.

Using Walter's formulae as a basis, we developed a short computer program for our antiquated Apple II Plus. Written to compute needed wing twist, it ran very rapidly and gave twist values comparable to several known successful designs.

Alan Halleck, of Portland, Oregon, is a fellow "'wing nut" and computer freak with whom we converse on a regular basis. Knowing Alan would be interested, we sent down a hard copy of this small program for him to enter into his IBM compatible. Since there are no graphics involved and the commands used are parallel for both versions of BASIC he was able to enter it with no problem, and Alan immediately set to work designing a flying wing using a couple of airfoils designed by Martin Hepperle.

An October '90 get together with Alan during which we spent several hours at his computer produced a much more sophisticated BASIC program. The program now prompts the user for airframe information such as span, chords and airfoils, sweep, projected weight, and other information. The printout shows the wing area, location of the neutral point, CG location based on a series of stability factors, wing loading, and of course the twist required for a given coefficient of lift. It's easy to modify individual pieces of data to see the effect as all values remain constant from one run to another unless changed when prompted. All airfoil data required by the program is stored on disk, and placing airfoil data on disk is a simple task performed by a very small additional program.

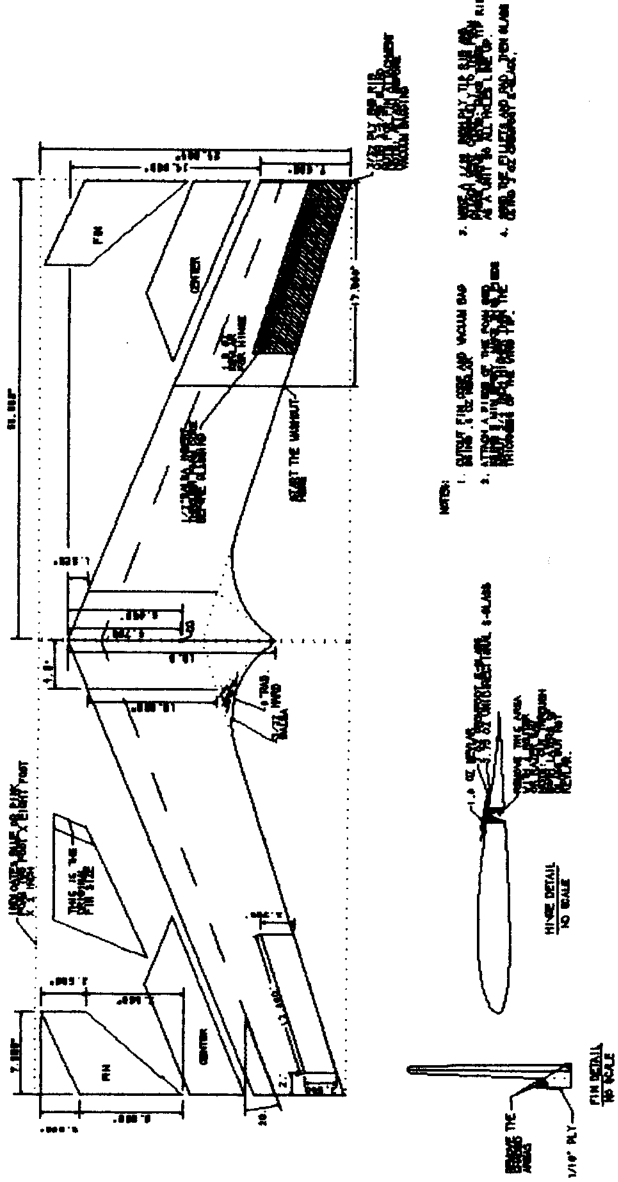
The result of Alan's design work is a bat-tailed $20^{\circ}$ sweep flying wing of 77" span. Winglets provide some vertical area, but elevons are the only control surfaces. Total washout is a minimal 1 1/2 degrees. The 'wing is of foam core construction with fiberglass and Kevlar providing the strength, and the entire structure is vacuum bagged. We've included a small sketch of the resulting planform. Alan located the CG according to the computer program and found it to be extremely accurate. Removal of weight to shift the CG rearward was met with a decrease in performance. This is proof again the program does deliver accurate information.

We had the opportunity of witnessing the RAZER1 in action at Goodnoe Hills on the Columbia River. During a high speed landing the 'wing flipped into the air and hit the rock surface of the hill inverted but survived without a scratch - it's one strong airplane! The RAZER1 is capable of some great aerobatics. It does good axial rolls and can fly inverted for extended periods. The turning radius is very small.

The proof of the RAZER1 design came at the November '90 slope race held by Alan's local club, the Portland Area Sailplane Society (PASS). In winds of 40 knots and above the RAZER1 performed admirably, taking second place in all heats and placing fifth overall out of 16 entries. Alan admits to not being well practiced for the event, and he missed a pylon on the last lap of the last race; otherwise his placing would have been higher.

New design, first race, pretty good performance, right? Well, there's more. The wing loading of the RAZER1 is about 10.7 oz. per sq. ft., yet it was competing against conventional tailed sailplanes loaded at 16 to 24 oz. per sq. ft. The rotor on the hilltop was viscious and ate several airplanes, but the RAZER1's single "hard landing" barely dented the nose.

We and Alan wish to Dr. Panknin for presenting his formulae to the modeling public at the '89 MARCS Symposium, as well as for so enthusiastically supporting the release of our computer program to readers of RCSD. The complete text of Walter's presentation at the '89 Symposium is within the Proceedings available from MARCS.



## APPLESOFT VERSION

INTRODUCTION TO THE PANKNIN TWIST PROGRAM:

This first program asks for certain data about your preliminary design. Initially, all will have zero values. Fill in data as requested. When complete, the program will print the input information along with a series of derived parameters. Following that, a sequence of stability factors, then the twist required, and the location of the CG for each stability factor. During the second and subsequent run throughs, the data originally input will be repeated on the screen. If you wish to retain this data, simply press <RETURN>. If a change is needed input the new data and then press <RETURN>. In this way the program can go through a series of single or multiple parameter changes, giving relevent information for each iteration.

```
10  TEXT : HOME :PO = 2
20  VTAB 10: PRINT "                 PANKNIN.TWIST"
30  FOR X = 0 TO 5000: NEXT X
42  HOME
45  ONERR  GOTO 5000
50  PRINT "PLANE TYPE OR NAME ------ = ";AC$: INPUT Z$: IF Z$ <  >
"" THEN AC$ = Z$
51  PRINT  CHR$ (4);"OPEN";AC$
52  PRINT  CHR$ (4);"READ";AC$
53  INPUT AC$
54  INPUT A$
55  INPUT B$
56  INPUT LW
57  INPUT LA
58  INPUT B
59  INPUT PF
60  INPUT CA
61  INPUT W
70  PRINT  CHR$ (4);"CLOSE";AC$
78  PRINT "AIRFOIL NAME ROOT ---- = ";A$;"  ";: INPUT Z$: IF Z$ <
> "" THEN A$ = Z$
79  PRINT "               TIP  ---- = ";B$;"  ";: INPUT Z$: IF Z$ <
> "" THEN B$ = Z$
80  PRINT "ROOT CHORD -------------- = ";LW;"  ";
100  INPUT Z$: IF Z$ <  > "" THEN LW =  VAL (Z$)
110  PRINT "TIP CHORD --------------- = ";LA;"  ";
130  INPUT Z$: IF Z$ <  > "" THEN LA =  VAL (Z$)
140  PRINT "SPAN        -------------- = ";B;"  ";
160  INPUT Z$: IF Z$ <  > "" THEN B =  VAL (Z$)
170  PRINT "SWEEPBACK ANGLE OF 1/4 CHORD LINE = ";PF;"  ";
190  INPUT Z$: IF Z$ <  > "" THEN PF =  VAL (Z$)
200  PRINT "CALCULATE WITH CL = ";CA;"  ";
220  INPUT Z$: IF Z$ <  > "" THEN CA =  VAL (Z$)
230  PRINT "WEIGHT IN OUNCES = ";W;"  ";
250  INPUT Z$: IF Z$ <  > "" THEN W =  VAL (Z$)
260  PRINT  CHR$ (4);"OPEN";A$
265  PRINT  CHR$ (4);"READ";A$
270  INPUT NR$,CL(1),CD(1),OW,MW,TH(1),CR
280  PRINT  CHR$ (4);"CLOSE";A$
```

```
290  PRINT  CHR$ (4);"OPEN";B$
295  PRINT  CHR$ (4);"READ";B$
300  INPUT NT$,CL(2),CD(2),OA,MA,TH(1),CT
310  PRINT  CHR$ (4);"CLOSE";B$
320 TM = (LW + LA) / 2:AR = B / TM
330 TR = LA / LW
340  PRINT : PRINT
350  PRINT "IF YOU WISH A PRINTOUT OF THE DATA, PRESS <P>": PRINT
"THEN <ENTER> NOW!": PRINT : PRINT "FOR NO PRINTOUT, PRESS
<ENTER> ALONE."
360  INPUT Z$: PRINT Z$: IF Z$ = "P" THEN  PRINT  CHR$
(4)"PR#";PO: PRINT  CHR$ (9);"I80N" : REM  <CNTRL> <I> to set
printer to 80 columns
370  HOME
380  PRINT "AIRCRAFT NAME: ";AC$: PRINT "ROOT SECTION = ";A$:
PRINT "TIP SECTION = ";B$
390  PRINT "ROOT CHORD = ";LW: PRINT "TIP CHORD = ";LA
400  PRINT "SPAN = ";B: PRINT "SWEEP ANGLE OF 1/4 CHORD LINE =
";PF: PRINT "WEIGHT = ";W;" OUNCES": PRINT "CALCULATED FOR CL =
";CA
410  PRINT : PRINT
420  PRINT "AVERAGE CHORD = ";TM: PRINT "TAPER RATIO = ";TR
430  PRINT "ASPECT RATIO = ";AR
440 K1 = 1 / 4 * (3 + 2 * TR + TR ^ 2) / (1 + TR + TR ^ 2)
450 K2 = 1 - K1
460 B1 = B / 2
470 D =  TAN (PF * 3.1414927 / 180) * B1
480 L1 = LW * .25
490 L2 = LA * .25
500 D1 = (L1 - L2) + D
510 AC = (LW ^ 2 + (LW * LA) + LA ^ 2) / (6 * (LW + LA)) + (((2 *
LA) + LW) * D1) / (3 * (LW + LA))
520  PRINT "AERO CENTER = ";AC;" INCHES": PRINT "BEHIND LEADING
EDGE AT ROOT"
530  PRINT : PRINT "D1 (DISTANCE LE WINGTIP BEHIND LE ROOT)":
PRINT "= ";D1: PRINT
540  PRINT "WING AREA = ";B * TM;"SQ. IN.": PRINT  TAB( 13)B * TM
/ 144;"SQ. FT."
550  PRINT "WING LOADING = ";W / (B * TM / 144);" OZ./SQ. FT."
560  INPUT Z$: PRINT Z$: HOME
570  FOR ST = .01 TO .03 STEP .005: GOSUB 610: NEXT ST
580  INPUT Z$: PRINT Z$: HOME
590  FOR ST = .035 TO .051 STEP .005: GOSUB 610: NEXT ST
600  PRINT  CHR$ (4);"PR#0": INPUT Z$: PRINT Z$
605  PRINT "DO YOU WANT THE RAW DATA SAVED TO DISK? (Y/N)";:
INPUT Z$: IF Z$ = "Y" THEN  GOTO 900
607  PRINT "ANOTHER? (Y/N)";: INPUT Z$: IF Z$ = "Y" THEN  GOTO
50
608  END
610 TWIST = ((K1 * MW + K2 * MA) - CA * ST) / (.000014 * AR ^
1.43 * PF)
620  PRINT "ST = ";ST;"    AERO TWIST = ";TWIST
630 TWIST = TWIST - (OW - OA)
640  PRINT "                  GEO TWIST = ";TWIST
650 CG = AC - TM * ST
660  PRINT "     CG = ";CG: PRINT "     FROM LE AT ROOT"
670  PRINT
```

```
680  RETURN
900  REM  DISK SAVE
910  HOME : PRINT "THIS AIRCRAFT IS CURRENTLY NAMED ";AC$
920  PRINT : PRINT "IF THIS IS OK, PRESS <ENTER>, OTHERWISE ENTER
THE NEW NAME"
930  INPUT Z$: IF Z$ <  > "" THEN AC$ = Z$
950  HOME : PRINT "SAVING TO DISK..."
1020  PRINT  CHR$ (4)"OPEN";AC$
1022  PRINT  CHR$ (4)"DELETE";AC$
1024  PRINT  CHR$ (4)"OPEN";AC$
1026  PRINT  CHR$ (4)"WRITE";AC$
1100  PRINT AC$
1110  PRINT A$
1120  PRINT B$
1130  PRINT LW
1140  PRINT LA
1150  PRINT B
1160  PRINT PF
1161  PRINT CA
1162  PRINT W
1170  PRINT  CHR$ (4)"CLOSE";AC$
1180  GOTO 607
5000 E1 =  PEEK (222): PRINT "ERROR #";E1: IF E1 = 5 THEN  PRINT
"NO FILE BY THAT NAME": GOTO 78
5001  END
```

**INTRODUCTION TO THE AIRFOIL DATA PROGRAM:**

This small program places input airfoil information on disk for use by the above program. Other programs, of your own design perhaps, can be written to make use of the information as well. The program runs in a self explanatory manner.

```
10  TEXT : HOME
20  PRINT "AIRFOIL NAME = ": PRINT "ENTER 'DONE' IF NO MORE ";:
INPUT N$
30  IF N$ = "DONE" THEN  END
40  INPUT "CL = ";CL
50  INPUT "CD = ";CD
60  INPUT "ZERO LIFT ANGLE = ";ZLA
70  INPUT "PITCHING MOMENT = ";CM
80  INPUT "THICKNESS = ";TH
90  INPUT "CAMBER = ";C
100  PRINT  CHR$ (4)"OPEN";N$
110  PRINT  CHR$ (4)"DELETE";N$
120  PRINT  CHR$ (4)"OPEN";N$
130  PRINT  CHR$ (4)"WRITE";N$
140  PRINT N$
150  PRINT CL
160  PRINT CD
170  PRINT ZLA
180  PRINT CM
190  PRINT TH
200  PRINT C
210  PRINT  CHR$ (4)"CLOSE";N$
220  GOTO 10
```

## FOR IBM and IBM COMPATIBLES

### INTRODUCTION TO THE PANKNIN TWIST PROGRAM:

This first program asks for certain data about your preliminary design. Initially, all will have zero values. Fill in data as requested. When complete, the program will print the input information along with a series of derived parameters. Following that, a sequence of stability factors, then the twist required, and the location of the CG for each stability factor. During the second and subsequent run throughs, the data originally input will be repeated on the screen. If you wish to retain this data, simply press <RETURN>. If a change is needed input the new data and then press <RETURN>. In this way the program can go through a series of single or multiple parameter changes, giving relevent information for each iteration.

```
10  CLS
20  PRINT "                         **********   PANKNIN TWIST
**********"
30  FOR X = 0 TO 5000 : NEXT X
45  ON ERROR GOTO 5000
50  CLS : PRINT "PLANE TYPE OR NAME ------ = "; AC$:  INPUT Z$: IF
Z$<>"" THEN AC$ = Z$
52  OPEN "I",#1,AC$
53  INPUT #1,AC$
54  INPUT #1,A$
55  INPUT #1,B$
56  INPUT #1,LW
57  INPUT #1,LA
58  INPUT #1,B
59  INPUT #1,PF
60  INPUT #1,CA
61  INPUT #1,W
70  CLOSE #1
78  PRINT "AIRFOIL NAME  ROOT ----- = ";A$: INPUT Z$:IF Z$<>""
THEN A$ = Z$
79  PRINT "                TIP  ----- = ";B$: INPUT Z$:IF Z$<>""
THEN B$ = Z$
80  PRINT "ROOT CHORD --------------- = ";: IF LW = 0 THEN GOTO 100
90  PRINT LW
100  INPUT Z$:IF Z$<>"" THEN LW - VAL(Z$)
110  PRINT "TIP CHORD ---------------- = ";:IF LA = 0 THEN GOTO 130
120  PRINT LA
130  INPUT Z$:IF Z$<>"" THEN LA = VAL(Z$)
140  PRINT "SPAN        --------------- = ";:IF B = 0 THEN GOTO 160
150  PRINT B
160  INPUT Z$:IF Z$<>"" THEN B = VAL (Z$)
170  PRINT "SWEEPBACK ANGLE OF 1/4 CHORD LINE = ";:IF PF = 0 THEN
GOTO 190
180  PRINT PF
190  INPUT Z$:IF Z$<>"" THEN PF = VAL(Z$)
200  PRINT "CALCULATE WITH CL = ";:IF CA = 0 THEN GOTO 220
210  PRINT Z$
```

```
220  INPUT Z$:IF Z$<>"" THEN CA = VAL(Z$)
230  PRINT "WEIGHT IN OUNCES = ";:IF W= 0 THEN GOTO 250
240  PRINT W
250  INPUT Z$:IF Z$<>"" THEN W = VAL(Z$)
260  OPEN "I",#1,A$
270  INPUT #1,NR$,CLR,CDR,OW,MW,THR,CR
280  CLOSE #1
290  OPEN #1,#1,B$
300  INPUT #1,NT$,CLT,CDT,OA,MA,THT,CT
310  CLOSE #1
320  TM = (LW + LA) / 2:AR = B / TM
330  TR = LA / LW
340  PRINT : PRINT
350  PRINT "IF YOU WISH A PRINTOUT OF THE DATA, PRESS <CTRL> AND
<PRINT SCREEN>," : PRINT "THEN <ENTER> NOW!": PRINT : PRINT "FOR
NO PRINTOUT, PRESS <ENTER> ALONE."
360  INPUT Z$: PRINT Z$
370  CLS
380  PRINT "AIRCRAFT NAME: "; AC$: PRINT "ROOT SECTION = "; A$:
PRINT "TIP SECTION = ";B$
390  PRINT "ROOT CHORD = ";LW: PRINT "TIP CHORD = ";LA
400  PRINT "SPAN = ";B: PRINT "SWEEP ANGLE OF 1/4 CHORD LINE =
";PF: PRINT "WEIGHT = ";W;" OUNCES": PRINT "CALCULATED FOR CL =
";CA
410  PRINT : PRINT
420  PRINT "AVERAGE CHORD = ";TM: PRINT "TAPER RATIO = ";TR
430  PRINT "ASPECT RATIO = ";AR
440  K1 = 1/4 * (3 + 2 * TR + TR ^ 2)/(1 + TR + TR ^ 2)
450  K2 = 1 - K1
460  B1 = B / 2
470  D = TAN (PF * 3.1414927 / 180) * B1
480  LW1 = LW * .25
490  LA1 = LA = .25
500  D1 = (LW1 - LA1) + D
510  AC = (LW ^ 2 + (LW * LA) + LA ^ 2) / (6 * (LW + LA)) + (((2
* LA) + LW) * D1) / (3 * (LW + LA))
520  PRINT "AERODYNAMIC CENTER = ";AC;" INCHES BEHIND LEADING
EDGE AT ROOT"
530  PRINT : PRINT "D1 (DISTANCE LEADING EDGE OF WINGTIP": PRINT
"IS BEHIND LEADING EDGE OF ROOT) = ";D1: PRINT
540  PRINT "WING AREA = ";B * TM;"SQ. IN.": PRINT TAB(13) B * TM
/ 144;"SQ. FT."
550  PRINT "WING LOADING = ";W / (B * TM / 144);" OZ./SQ. FT."
560  INPUT Z$: PRINT Z$ : CLS
570  FOR ST = .01 TO .03 STEP .005: GOSUB 610 : NEXT ST
580  INPUT Z$: PRINT Z$ : CLS
590  FOR ST = .035 TO .051 STEP .005: GOSUB 610 NEXT ST
600  INPUT Z$: PRINT Z$
605  PRINT "DO YOU WANT THE RAW DATA SAVED TO DISK? (Y/N)";:INPUT
Z$:IF Z$ = "Y" THEN GOTO 900
607  PRINT "ANOTHER? (Y/N)";:INPUT Z$: IF Z$ = "Y" THEN GOTO 50
608  END
610  TWIST = ((K1 * MW + K2 * MA) - CA * ST) / (.000014 * AR ^
1.43 * PF)
620  PRINT "ST = ";ST; "     AERODYNAMIC TWIST REQ'D = ";TWIST
```

```
630  TWIST = TWIST - (OW - OA)
640  PRINT"                  GEOMETRIC TWIST REQ'D = ";TWIST
650  CG = AC - TM * ST
660  PRINT"                  CG = ";CG;" BACK FROM LEADING EDGE AT
ROOT"
670  PRINT
680  RETURN
900  REM DISK SAVE
910  CLS : PRINT "THIS AIRCRAFT IS CURRENTLY NAMED ";AC$
920  PRINT : PRINT "IF THIS IS OK, PRESS <ENTER>, OTHERWISE ENTER
THE NEW NAME"
930  INPUT Z$: IF Z$<>"" THEN AC$ = Z$
950  CLS : PRINT "SAVING TO DISK..."
1020  OPEN "O",#1,AC$
1100  PRINT #1,AC$
1110  PRINT #1,A$
1120  PRINT #1,B$
1130  PRINT #1,LW
1140  PRINT #1,LA
1150  PRINT #1,B
1160  PRINT #1,PF
1161  PRINT #1,CA
1162  PRINT #1,W
1170  CLOSE #1
1180  GOTO 607
5000  RESUME 78
```

INTRODUCTION TO THE AIRFOIL DATA PROGRAM:

This small program places input airfoil information on disk for use by the above program. Other programs, of your own design perhaps, can be written to make use of the information as well. The program runs in a self explanatory manner.

```
5  PRINT "AIRFOIL NAME = ": PRINT "ENTER 'DONE' IF NO MORE ";:
INPUT N$
10  IF N$ = "DONE" THEN END
40  INPUT "CL = ";CL
50  INPUT "CD = ";CD
60  INPUT "ZERO LIFT ANGLE = ";ZLA
70  INPUT "PITCHING MOMENT = ";CM
80  INPUT "THICKNESS = ";TH
90  INPUT "CAMBER = ";C
95  OPEN "O",#1,N$
100  PRINT #1,N$
110  PRINT #1,CL
120  PRINT #1,CD
130  PRINT #1,ZLA
140  PRINT #1,CM
150  PRINT #1,TH
160  PRINT #1,C
170  CLOSE #1
180  GOTO 5
```

## "SCHWANZLOSE FLUGZEUGE" REVIEW

A review of "Schwanzlose Flugzeuge: Ihre Auslegung und ihre Eigenschaften" ("Tailless Aircraft: Their Layout and Qualities"), a new book written in German by Dr. Karl Nickel and Dr. Michael Wohlfahrt and published in 1990 by Birkhauser Verlag of Basel, Germany.

Dr. Karl Nickel, a test pilot for several of the Horten designs, and Dr. Michael Wohlfahrt, designer of RC flying wings for the Swiss LOGO F3B Team, have written what is advertised as "the bible" for anyone interested in tailless aircraft. "Schwanzlose Flugzeuge" does not focus on models, although an immense amount of material of use to modelers is presented. Rather, it lives up to its title by covering all sizes of tailless aircraft. The book is dedicated to the memory of Franz Xaver Wortmann, designer of the FX series of airfoils.

As objectively written books are becoming more difficult to find, it was a welcome surprise to find the statement, "Das Nurflugelflugzeuge ist der Flugzeug der Zukunft." ("The wing-only aircraft is the aircraft of the future.") followed by, "Wir, die Autoren deises Buches, sind davon nicht uberzeugt!" ("We, the authors of this book, are about this not convinced!").

This hardcover book consists of 616 pages divided into 12 chapters plus a forward, literature list/bibliography, a complete listing of terms as used in formulae, and a comprehensive index. Each chapter is divided into several sections, averaging six to seven per chapter, and all formulae, drawings, and photographs are serially numbered. It is written, then, in the style of a textbook. The main thrust of the book is to fully illuminate problems, construction, and flying characteristics of all types of tailless aircraft. The authors' goals are assisted throughout by headings denoting special consideration: problems, goals, history, explanations and descriptions, applications, cautions, and additional material. Boldface type is used to increase the reader's attention to important points.

"Schwanzlose Flugzeuge" does not assume the reader to be knowledgeable, and in fact begins with a definition of tailless aircraft and an explanation of their physical relationship to conventional tailed aircraft. The second chapter, in explaining basic aerodynamics and associated terminology, carefully examines aerodynamic theory as related to tailless aircraft. The aim here is to provide the reader with the information needed to understand the polar diagrams, lift distribution curves, and formulae given later.

Stability, control surfaces and their effects, and flying characteristics are covered in the next three chapters. Stability is related to the neutral point and several other measureable parameters, and the effects of control surface movements on stability are examined, including aileron differential, flaps, and air brakes. Chapter 5, concerned with flying characteristics, provides some details about the effectiveness of wing twist, boundary layer fences, and slots.

Once a preliminary design is chosen, the next logical step is to optimize it. Maximizing lift, minimizing drag, and the use and design of winglets is examined of achieving greater efficiency and better control. Chapter 7 continues this discussion through an examination of various wing profiles, sweep, twist, winglets, and flaps. Of particular note is a complete quotation of Barnaby Wainfan's article on reflexed profiles which appeared in the December 1988 issue of Kitplanes magazine.

The problems of tailless aircraft are in some cases unique while others are similar to those seen in conventional tailed aircraft. Flutter and boundary layer drift are of course associated with swept wings of any kind, but increasing elevator function without adverse effect and moving the CG to increase performance pose special problems for tailless aircraft.

Perhaps the most surprising part of "Schwanzlose Flugzeuge" is Chapter 9, in which hang gliders are described as ideal tailless aircraft! Radio controlled models are covered in Chapter 10, with many photographs and a most interesting profile of an F3B winch launch trajectory.

"Stories, misjudgements, prejudice and fairy tales" is the title of Chapter 11. It is here we learn the truth about such things as the bell shaped lift curve, the middle effect, and wandering of the boundary layer.

The final chapter describes in some detail both full sized aircraft (Lippisch Delta I and Horten I, Fauvel AV 36, Horten II, III, IV and VI, the SB 13 "Arcus", and the Rochelt "Flair 30," an ultralight sailplane), and Wohlfahrt's "Sapperlot," the 'wing he's designed for the Swiss LOGO-Team.

As you can see from the above outline, "Schwanzlose Flugzeuge" covers its material in logical order. Information is provided in an easily comprehended way, with later concepts always easily related to those presented earlier.

The literature list/bibliography is quite extensive, with several citations credited to Dr. Nickel, and several more to Dr. Wohlfahrt. We should also mention the first citation, which is out of alphabetical order, and which Nickel and Wohlfahrt describe as "the well detailed literature list" for tailless aircraft. That citation is for Serge Krauss' "Tailless Aircraft - An Extensive Bibliography for Subsonic Types." This is quite an honor for Serge, and it is well deserved.

"Schwanzlose Flugzeuge" lives up to its billing as the bible of tailless fans. Although published by Birkhauser, copies are available through Verlag fur Technik und Handwerk, GmbH, the publisher of the German magazine FMT. The cost is DM78,00. While this totals something over US$50.00, we consider the book to be of significant value and there is no question ordering through VTH is the least expensive method of acquiring it. Orders are shipped immediately upon receipt, but delivery takes roughly five weeks as items are sent by surface mail. Again, "Schwanzlose Flugzeuge" is written entirely in German.

"Faszination Nurflugel," edited by Hans-Jurgen Unverferth, was reviewed in this column in the April 1990 issue of RCSD. Less expensive (DM29,50), a focus on models only, more easily understood graphs, relevent photographs, and quite a bit of construction information in the form of drawings make "Faszination Nurflugel" the more practical choice if your knowledge of German is less than good. "Faszination Nurflugel" is also available directly from Verlag fur Technik und Handwerk, GmbH, under the same terms as outlined above.

## "TAILLESS BIBLIOGRAPHY" REVIEW

This bibliography was first brought to our attention by a correspondent who mentioned a classified advertisement in one of the magazines catering to enthusiasts of homebuilt aircraft. Our request for additional information was met with a prompt reply, and we ordered a copy for our personal library.

A complete and accurate overview of the contents of "Tailless Aircraft" is best left to Mr. Krauss:

"After more than a year's work, I have just released a bibliography of literature concerning subsonic tailless aircraft and related topics. An outgrowth of a personal hobby, it began as an attempt simply to catalog my holdings and to save others some of the effort necessary to find the thousand or more tailless items I had or knew about from several years of enthusiastic nosing around. It has since grown to include nearly 1500 tailless items, 500 items of related interest, and other information of an annotative nature. The entire document contains over 120 pages. It is, to my knowledge, unique and the largest work of its kind ever published.

"My main intent in publishing this work has been to provide a bibliography substantial in its treatment of historical and technical literature concerning tailless development and technique, and well-rounded with respect to other topics of tailless interest. While such a document can be neither comprehensive nor exhaustive, this is an extensive work, encompassing literature ranging from magazine articles through patents and technical reports, and dating from the late nineteenth century to the present. Historians and those interested in design and construction of tailless aircraft should find its listings useful.

"In addition to chronological listings of material on tailless aircraft and related topics, the bibliography includes other helpful information. A preface furnishes a brief perspective on tailless development and its chief proponents. Introductory material includes discussion of tailless guidelines, content and format of the bibliography, information on acquisition of tailless aircraft information, and suggestions for reasonable core material from the tailless literature. Listed items are commonly accompanied by notations concerning topic, content, length, presentational features, and sometimes other cross-referential material or sources. Brief lists of previous bibliographies and sources of rare materials are also included. Finally, an appendix lists dates for tailless aircraft by more than 100 selected designers.

"The book is spiral bound (helically) in durable patchco grained material, so that it can be opened back on itself without folding or otherwise damaging its pages. It can also be dragged through library stacks - or wherever - with a minimum of wear."

The preface remains our favorite part of the book. It is here, in the opening pages, that we read about a few of the notable designers and their approaches to the unique problems of tailless aircraft. Mr. Krauss, however, goes further. He explains the underlying drives which relentlessly force those individuals to persist, sometimes in the face of strong personal and monetary adversity. We, not too surprisingly, see inklings of these drives in ourselves, and so the preface lends support to some of our own goals, while at the same time reminding us of the existence of fallacies.

As genuine tailless and flying wing fanatics, we have devoured this book several times over. After more than a year it still serves as an efficient source of information, and it has in fact stimulated us to catalog our own collection of materials dealing with tailless aircraft.

The first edition of "Tailless Aircraft - An Extensive Bibliography for Subsonic Types" was printed in December of 1989. Serge adds to the tailless bibliography as he finds materials not previously listed and updates it with recent citations. A copy of the current version is available directly from Mr. Krauss.

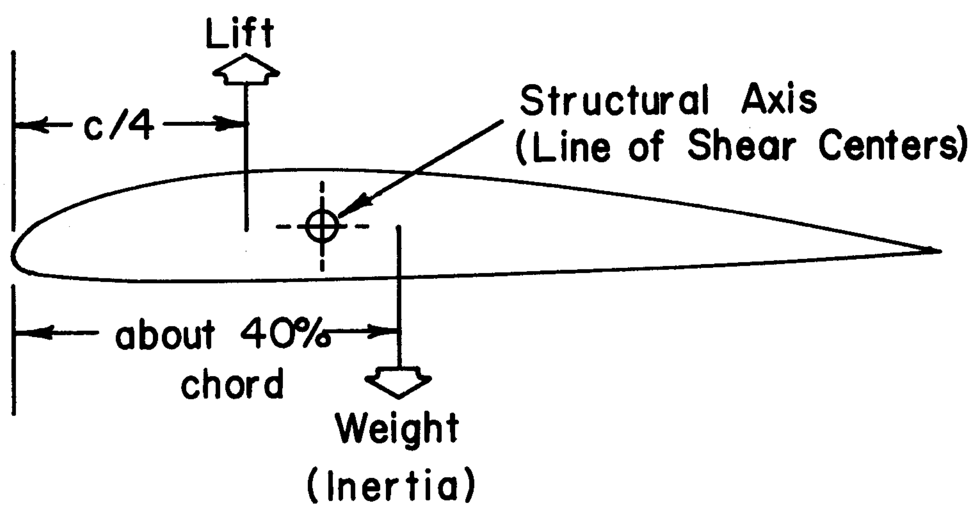
## INHIBITING FLUTTER

The description of Project Penumbra which appeared in the October 1990 issue of RCSD elicited several requests for the Penumbra.1 and Penumbra.2 sketches. Additionally, we've received a couple of pieces of correspondence from Bill Kubiak outlining the causes of flutter and offering some possible solutions. (If you'll remember, Penumbra.2 seemed to be very prone to flutter during launch. So severe was the flutter that one launch saw the right winglet shake off!) Bill's explanation is very clear and is applicable to conventional aircraft as well as our tailless creations, so we decided to reprint it here in our column.

"I also am interested in 'wings, dating back to '49 when I was at Northrop and did a small job on the YB-49 and the Snark. My modeling of 'wings, however, is limited to hand launch gliders of various configurations.

"You seem to be concerned with the higher speed of the 'wings and with flutter and other structural considerations. Well, let me throw out a few remarks to see if I can help you a little.

"Consider:



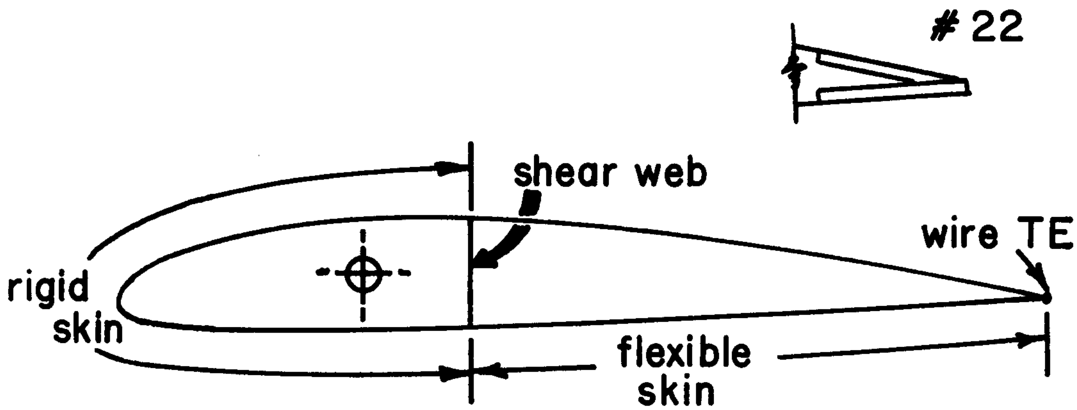
"The structural axis is a point through which you can apply a load without twisting the wing. Up loads ahead of the structural axis cause the wing to twist leading edge up; up loads aft of the structural axis cause the wing to twist leading edge down. The location of the structural axis varies with the design but generally, for enclosed sections, is at or near the centroid of the enclosed area. (The centroid is the center of mass of an object having a constant density. If a wing were composed of foam only, for example, the centroid would be at the CG of the wing.) So it usually happens that the centroid is located as shown above. Since inertia is always opposite to the lift we always have a couple tending to twist the wing about the structural axis.

"The location of the lift vector is pretty well fixed, so the thing to do is move the structural axis forward toward the lift and to move the inertia forward. This would reduce the destabilizing couple. If you went to extremes you might even get the centroid and structural axis ahead of the lift.

"I'm sure you are familiar with balancing an aileron or elevator at its hingeline (or maybe a little ahead) to prevent flutter. The same thing applies to a wing. The structural axis is the hinge line that the wing twists about. If you can get the inertia ahead of the structural axis then an up gust will give a leading edge down twist to the wing, relieving the gust twist.

"As an aside: In the '50's I was at McDonnell Aircraft in the structures department. John Meyer, Chief of Structures, wrote a memo about wing design and flutter. He said that the F3H Demon wing had about 1500 lbs. of structure beyond what was required to take shear and bending loads, just to make that thin sweptback wing flutter resistant. In comparison, an examination of a captured MiG-15 showed that Mikoyan and Gurevich had accomplished the same thing by installing A 60 Lbs. weight in the leading edge of each wing tip. The weight moved the wing CG ahead of the structural axis to reduce or prevent flutter. While it is deliberate heresy to consider ballast weight in an airplane, this is one case of one pound of ballast replacing over 12 lbs. of structure.

"I know that D-tube leading edges are in disrepute because of aerodynamic reasons concerning the discontinuity of curvature at the rear edge of the "D." But, a D-tube leading edge really makes sense from a structural point of view.




"If a wing were to be constructed as shown above, with a D-tube leading edge having a skin rigid enough to carry the shear load and a rear portion consisting of a flexible (Monokote) skin and a wire trailing edge (ala WWI airplanes) the structural axis could be at the C/4. The weight also could be forward so that we could have a very flutter resistant design.

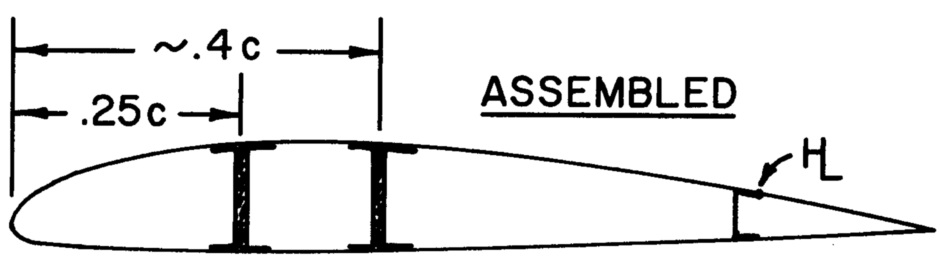
"My canard design #22 for John Borlaug was along these lines except that I didn't use a wire trailing edge. I used two 1/16" thick strips along the trailing edge. These strips are flexible in the vertical direction but are stiff horizontally to carry the Monokote loads. I can attest to the wing being flutter proof. I saw John perform a few horrendous dives without any sign of flutter. #22 met its demise while John was learning how to slope soar. He learned to never turn into the hill!

"I think part of your problem (with Penumbra.2) relates to the fact that you have a foam and fiberglass structure. I prefer open structures of balsa with a translucent covering because its so beautiful against the sky. I've never considered foam and opaque skin until now. So here comes a bunch of random thoughts about skin/foam structure.

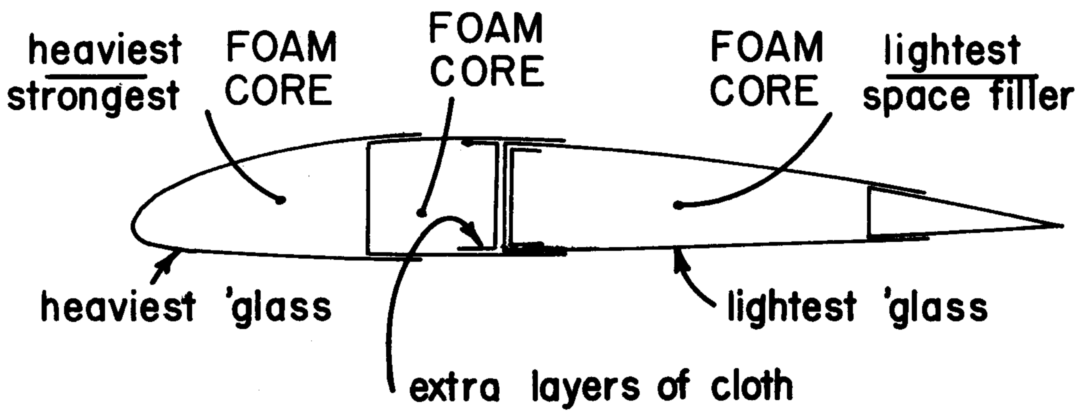
"When a wing deflects in bending the tip rises with respect to the root. The top surface is in compression and the bottom surface is in tension. When a beam deflects under load it tends to deflect in a manner to relieve the load. In a wing the top surface and the bottom surface want to deflect towards one another to decrease the depth of the beam. This reduces the strength of the beam so it can deflect to relieve the load.

"The tensile and compressive strength of fiberglass is about 200,000 lbs./in$^2$ until it buckles. The strength of foam is only about 1/1000 the strength of fiberglass. I really don't think the fiberglass even knows the foam is there.

"My first thought was to cut the foam core along a given percent chord from root to tip and put in a shear web. Vertical grain balsa of course. Balsa is 10 times stronger than foam (and 10 times heavier) but it's still not nearly as strong as fiberglass, so it isn't quite what we want. I think fiberglass shear webs would be the way to go if the vertical column strength is sufficient and if the web is fastened to the upper and lower skins with a strong joint.

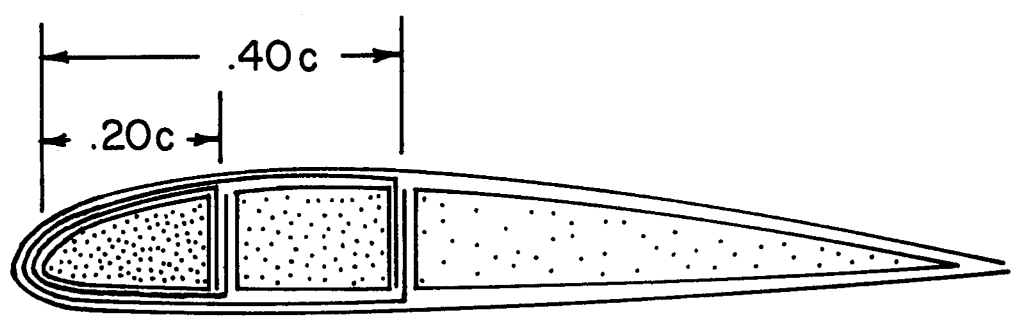


"Take a look at a Rutan Vari-EZE some time.




"The important thing to remember is that the shear web have sufficient strength to carry the compression loads tending to make the top and bottom surfaces touch."

An additional construction method using foam core(s) and fiberglass was described by Bill in a recent 'phone conversation. This is a vacuum bagged structure which provides both strength and mass in the forward portion of the wing. It is brobably similar to what some of you are doing already regarding formation of the D-tube, but the formation of the box spar is a noticeable improvement.




AN ALTERNATE, and stronger, METHOD

In response to all of this information, we're redesigning the entire Penumbra structure. The major changes are as follows:

(1) The spar system will be strengthened and moved forward, and unidirectional fiberglass cloth will be used to increase spanwise rigidity.

(2) One layer of bidirectional fiberglass will be placed with grain at 45 degrees to the wing's leading and trailing edges in an effort to increase torsional rigidity.

(3) Rigidity of the control surfaces, particularly the ailerons, will be monitored very closely, as will their own CG.

(4) Servos will be chosen with regard to lack of play at the output shaft, and linkages will be rigid.

We hope that you've gained as much from reading Bill's material as we have. John Borlaug's Counsellor, the canard that Bill mentions in this article, will be described in a future column.

## BILL KUBIAK "ON CANARDS"

In a previous column we promised more information about Bill Kubiak's Counsellor, a canard. The following article, describing canard design, originally appeared in Bill's club newsletter.

### ON CANARDS
by Bill Kubiak MRCSS

"I've been interested in canard type aircraft for a long time. My first canard was a hand-launched glider I made when I was in high school in 1943, followed by some stick ROG types and finally in 1947 an O&R 23 powered free flight. It flew very well until the rubber band holding the canard to the fuselage failed in flight. It was then that I discovered the advantages of using several rubber bands rather than one large long rubber band. In general, canards are stable, easy to adjust, forgiving of heavy handed tweaking, and they fly well.

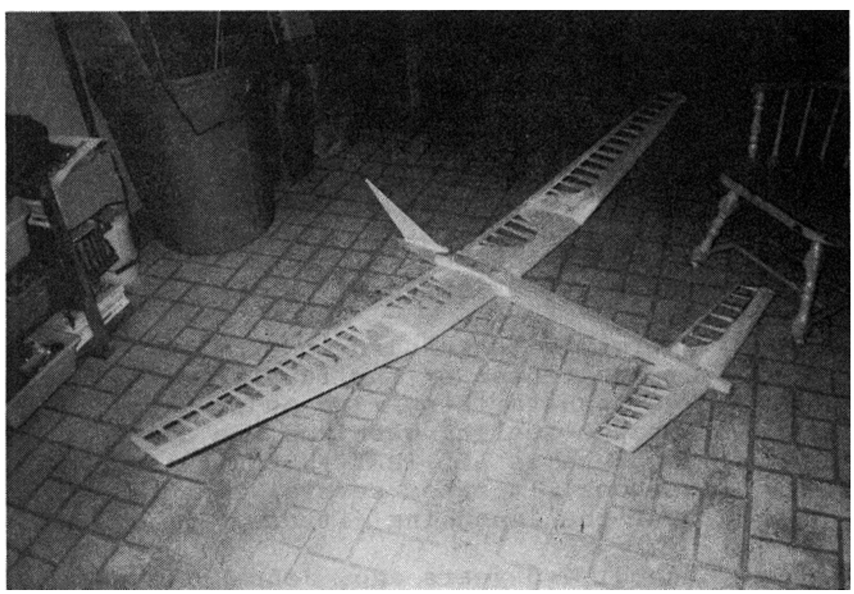
"Canard enthusiasts can usually quote several reasons why a canard is so desirable, especially in 1:1 scale. They are safe. The canard must stall first before the main wing in order to be stable. So the main wing never stalls, never spins, etc....

"They are also efficient. The tail downloading of conventional aircraft is replaced by an up load on the canard surface. This reduces the wing induced drag and so increases the overall efficiency of the aircraft.

"Canards are also very easy to lay out. In conventional 1:1 aircraft, especially in general aviation (small), the payload volume usually has to be located at the junction of the wing-fuselage load paths. Fuselage structure and wing carry-through design can usually be greatly simplified if you could just run a diagonal across the cockpit right through the pilot's chest. Cockpit design in a canard is a lot easier. The CG is ahead of the wing. The wing carry-through runs behind the cockpit. The canard loads run across the fuselage ahead of the cockpit. The cockpit is located in the center of the fuselage, and the pilot feels good without that diagonal running through his chest.

"But I think the greatest appeal of the canard is that it's different.

"Canard design is pretty straight forward. I have varied the area of the canard surface from 10% to 60% of the wing area, and have found 25-33% to be about best. I lay out the decalage at three degrees and add in six to 10 degrees of dihedral to the canard. The Vertical Tail Volume Coefficient is usually 0.02, and the main wing has about six degrees of dihedral. The forward fuselage at the canard needs some side area like a cabin or pylon. If it doesn't have the side area or dihedral the nose tends to fall in a turn. The canard surface should be located above the wing. It helps to have the canard tip above the ground when the fuselage and a wing are touching the ground.



"Whenever I build a model I weigh and balance the wing, fuselage, and tail parts after they are covered. After several years and several dozen model designs, I can estimate weight and balance of a new airframe quite accurately. I also weigh and balance the innards and draw them in place in my layout drawing. Then it's easy to calculate the weight and balance point location before the design is finalized. On a canard I locate the CG at 0.21 +/- 0.03 times the average chord ahead of the neutral point. I locate the towhook 1/2" ahead of the CG.

"Normally the canard model's towhook is about at the center of the fuselage. When you put the highstart tow-ring on the hook, it's a strange feeling when you are about to launch as there is ALL THAT FUSELAGE ahead of the towhook. It takes several launches to get over the launching jitters.

"About 4-5 years ago, John Borlaug started talking about building a canard model. I offered to design him one, but Craig Christenson had plans for a model called the "Weird One," published in Flying Models.

"John built that design and it flew very well. I continued with a canard design, which turned out to be model design #18, "Enalpria," in my long string of designs, but I didn't get a chance to build it then. John followed up his experience with the Weird One by doing a design of his own. It turned out to be very handsome design, but overweight. It's life was short for a variety of reasons, but it looked so darn good it would have been a shame to let it die. We took it over to my house, put a clean sheet of paper on the drawing board, and traced the profile of the fuselage and tail. Using that as the starting point, I designed a Standard Class that John called the Counsellor (or #22 in my books). It flew very well, including a 60 minute flight one lazy Saturday afternoon. Well, that got some enthusiasm going to build old #18, so last winter it was built and its been flying all this summer. Stability is good about all three axes, and it has good L/D. The only downfall is it is too light to penetrate well, so it can only be flown on days with winds below 15mph. It thermals well when someone like John is at the controls, but finding and riding thermals is not one of my skills.

"It has survived a launch with the receiver off, resulting in a spectacular pop-off and helicopter/frisbee return to earth. Ask Tom Rent for details as all I can remember is frantic blur.

"If you want to talk about flying canards, talk to John Borlaug. If you are interested in canard design, look me up."

## RED TAIL

Early in 1991 we received a package and letter from Willie Bosco of Garberville, California. The package contained a small balsa model constructed of some scraps left from a completed kit. Willie asked what we thought of the design and asked if we could make some suggestions concerning airfoil(s), location of CG, and methods of assuring stability in all three axes. The balsa model, although small and having just a flat plate airfoil, flew surprisingly well.

Willie has told us he has watched and flown with birds for years. Buzzards, Red Tailed Hawks, and Black Eagles are all in evidence in Northern California. At one time Willie considered getting a falconer's license to keep and train a Red Tailed Hawk. That dream was never pursued, but Willie did get involved in RC sailplanes. Little wonder Willie's 'ship looks like a bird!

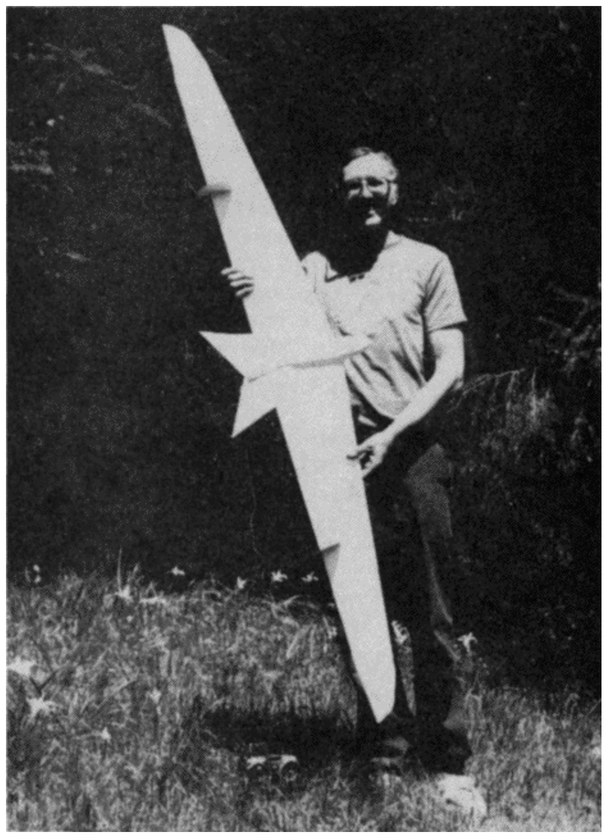
Willie's original drawings showed a rather novel method of roll control involving moveable wingtips. Since this was a new planform, and Willie's first flying wing, we suggested he stick with more conventional control methods. Failures would thus be traceable to basic difficulties with the design itself rather than being complicated by too many other variables.

The next package to arrive was a full sized drawing of what is now known as Red Tail. We made some other suggestions, such as location and size of the ailerons, setting up the elevator, and an easy method of gaining some directional stability, and printed some airfoil plots to be used as templates. The plans were then returned to Willie.

The next letter we received from Willie was most gratifying: "I appreciate your strong advice about all my wild ideas I had at first. I told my wife while I was building one night, 'Even if this doesn't fly it's been a great design and building process.' It was easy to bring my own ideas into reality once I could visualize what I had in mind.

The project moved right along and I finished it up last Sunday night on a marathon finish.

"I couldn't believe how the whole thing went from the time I cut the cores and sheeted them with veneer, to when the radio gear functioned, 'til when it balanced with only one ounce of lead in the nose, 'til when - and I'm not lying - it flew right out of my hand.



"I finished very late Sunday night. Monday, today, I went half way up my slope out my back yard for a hand toss. I didn't know what to expect. You can imagine my cool as it moved out, floated up, covered ground, rolled over and banked up, leveled out and sped home to my feet. That's when I knew that all your advice and my hard work paid off.

"The thing is a total success. It looks so good in the air and it is fast! It has already met and surpassed my expectations. I'm really happy!"

Red Tail operates on two channels: ailerons and elevator. Span is 82 inches, wing area is 468 $in^2$.; at a weight of 22 oz., the wing loading is under 7 oz./$ft^2$. As mentioned above, Red Tail utilizes a foam core and veneer skin; the body is fiberglass and epoxy, wrapped over a styrofoam mold; the elevator is sheet balsa. All radio gear is located within a removeable "nose cone" for accessibility. Construction is very rapid. Since Red Tail is capable of high speed, yet has a low wing loading, Willie feels he has a slope 'ship and a thermal machine all in one airframe.

We met and talked with Willie and saw Red Tail for ourselves at the Mid-Columbia Cup slope race in Richland the end of May 1991. Red Tail is a unique good flying design.

## PENUMBRA.4

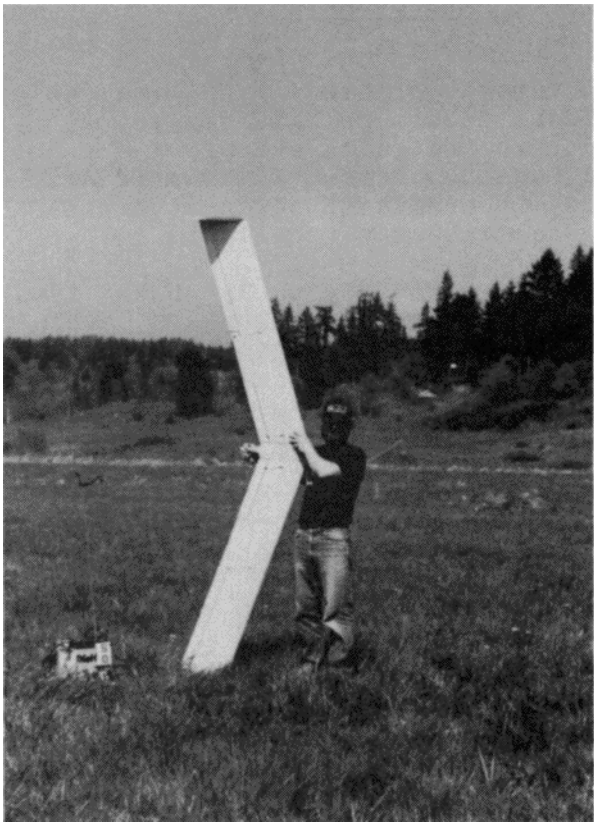
The fourth version of our flying wing design had its first flights on Saturday the 20th of April! Under the watchful eye of Dr. Walter Panknin, Penumbra.4 put in six successful flights out of seven attempts. Thermal performance was excellent.

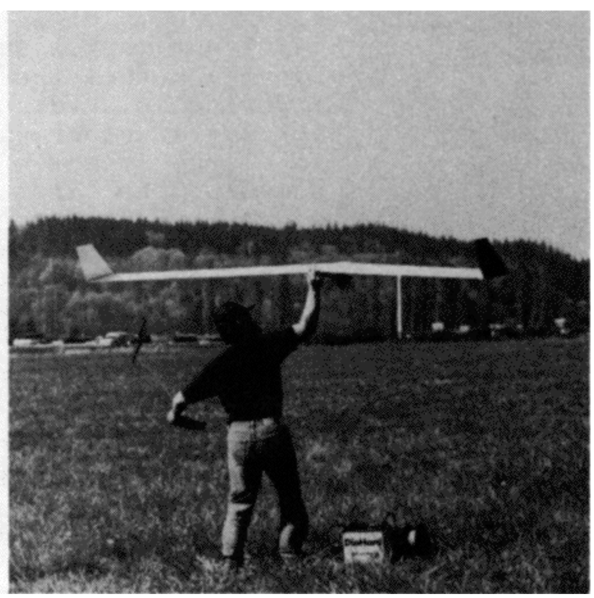
Dr. Panknin gave the "Flying Rainbows" flying wing presentation at the 1989 MARCS Symposium, an event covered in this column (RCSD 09/90). Walter's designs are of tapered planform with a root chord of sufficient length to completely enclose receiver and batteries. Structurally, his wings are of foam with wood veneer skin. Walter prefers using the Eppler 222 as the root section, and the Eppler 230 as the tip section.

Penumbra.4 utilizes a constant chord wing and the EH 1.0/9.0 airfoil. It has a shallow fuselage, and construction is of foam and fiberglass with a carbon fiber reinforced spar. Other than the wing leading adge and control surface faces, there is no wood in Penumbra.4's construction. Penumbra.4, therefore, stands in direct contrast to Dr. Panknin's creations.

Test flying Penumbra by the hand toss method was not completely successful. It is very difficult to get sufficient speed, even while running across the field into the wind and throwing as hard as possible. In an effort to get satisfactory glides from hand tosses, a too large amount of up trim was put into the elevons. The first winch launch attempt thus ended in a veer to the right and a spin to the ground. No damage was incurred, however, so the wing-fuselage junctions were retaped and some adjustments made. Elevon trim was lowered by three clicks and the towhook moved forward about 1.5 cm.

The second and all subsequent attempts were completely successful with no tracking problems noted. While it should be possible to reduce the elevon up trim and move the CG and towhook locations rearward, achieved launch height was completely acceptable. Flaps were not used during tow.



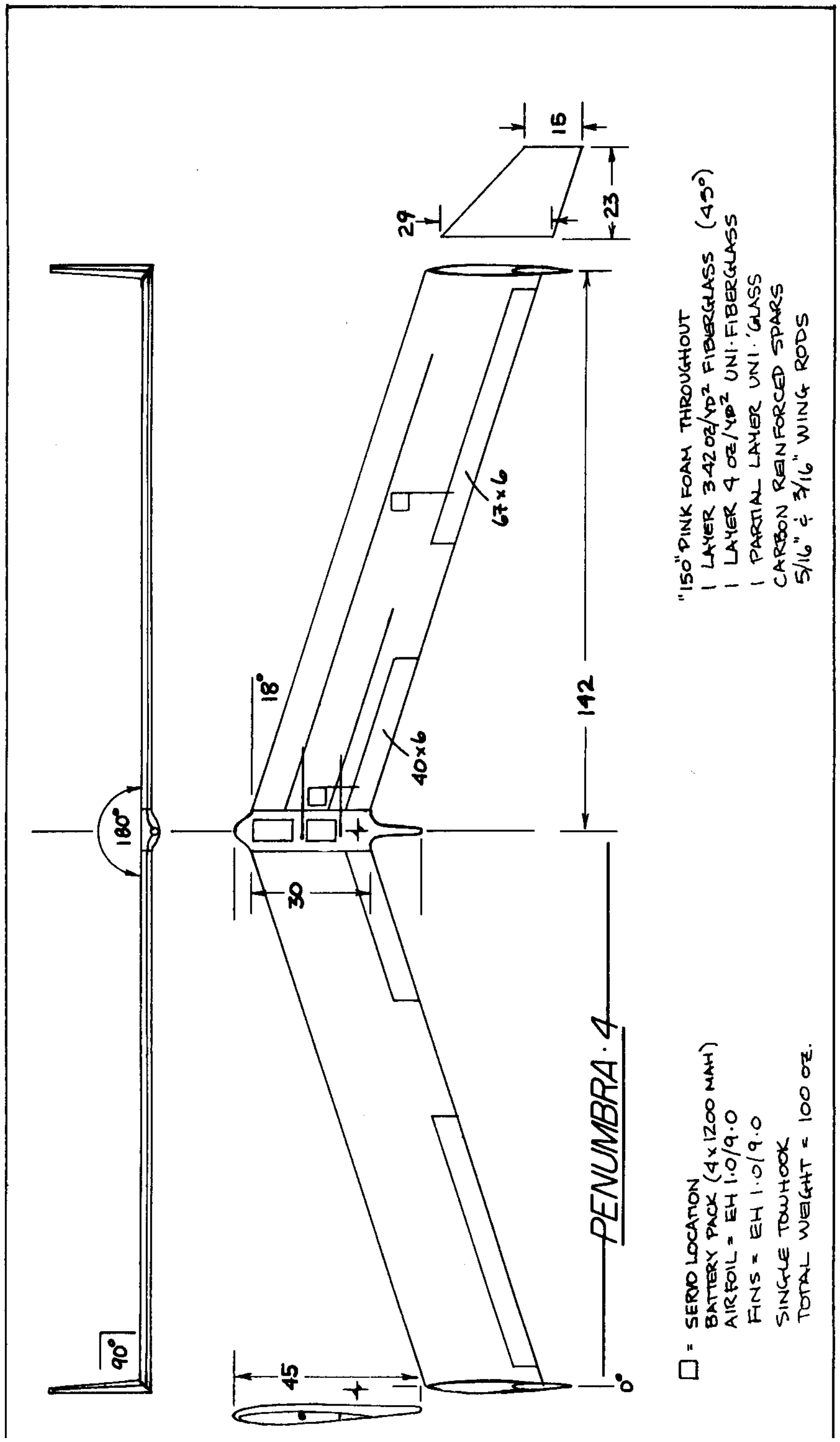


Penumbra.4 seems to be very sensitive to thermal activity, and was seen to be climbing at significant rates while traveling in a straight line. Thermal turns are a bit different than what we had expected. Our other elevon controlled 'wings, based on Dave Jones' Blackbird design, have all required opposite aileron to prevent spiraling in. Not so Penumbra. Once aileron control is neutralized this 'wing tends to come out of the turn. A small amount of right aileron must be input, therefore, along with a small amount of up elevator, to maintain a right turn.

Penumbra.4's speed range is very broad. With an approximate 10 knot breeze, it was possible to approach a hover when flying into the wind. A dive test to examine pitch recovery showed excellent acceleration and prolonged high speed flight in crosswind conditions. Launch height attained through zoom launches was very significant. Use of a small amount of positive flap during a landing approach showed the typical slight nose up pitching tendency; this was easily controlled with a small amount of down elevator. Landing speed did not seem to be affected with 20 degrees of flap deflection, but approximately 60 degrees is available.

All winch launches were accomplished by means of strong tension on the line, vigorous throwing of the 'wing straight out, and continuous power to the winch motor through the zoom. Only one minor episode of flutter was experienced, that during a strong zoom when the towline failed to come off at the appropriate time. The flutter lasted for only a couple of cycles and was extremely well damped. We do not consider this episode indicative of a significant problem.

Note: All photos for this column are courtesy of Dr. Panknin.


PENUMBRA · 4
"150" PINK FOAM THROUGHOUT
1 LAYER 3.42 OZ/YD² FIBERGLASS (45°)
1 LAYER 9 OZ/YD² UNI·FIBERGLASS
1 PARTIAL LAYER UNI·'GLASS
CARBON REINFORCED SPARS
5/16" & 3/16" WING RODS
□ = SERVO LOCATION
BATTERY PACK (4 x 1200 MAH)
AIRFOIL = EH 1.0/9.0
FINS = EH 1.0/9.0
SINGLE TOWHOOK
TOTAL WEIGHT = 100 OZ.
15
23
29
67 x 6
142
18°
40 x 6
180°
30
90°
45
0°

# NANOSAUR

We've been corresponding with Marc Vėpraskas for a couple of years now. During this time he's been attempting to design, build, and fly a thermal duration swept 'wing design utilizing the Eppler 222 - 230 series of airfoils and foam and balsa construction. He recently sent us the following report on his progress, together with a videotape of the first test flights.

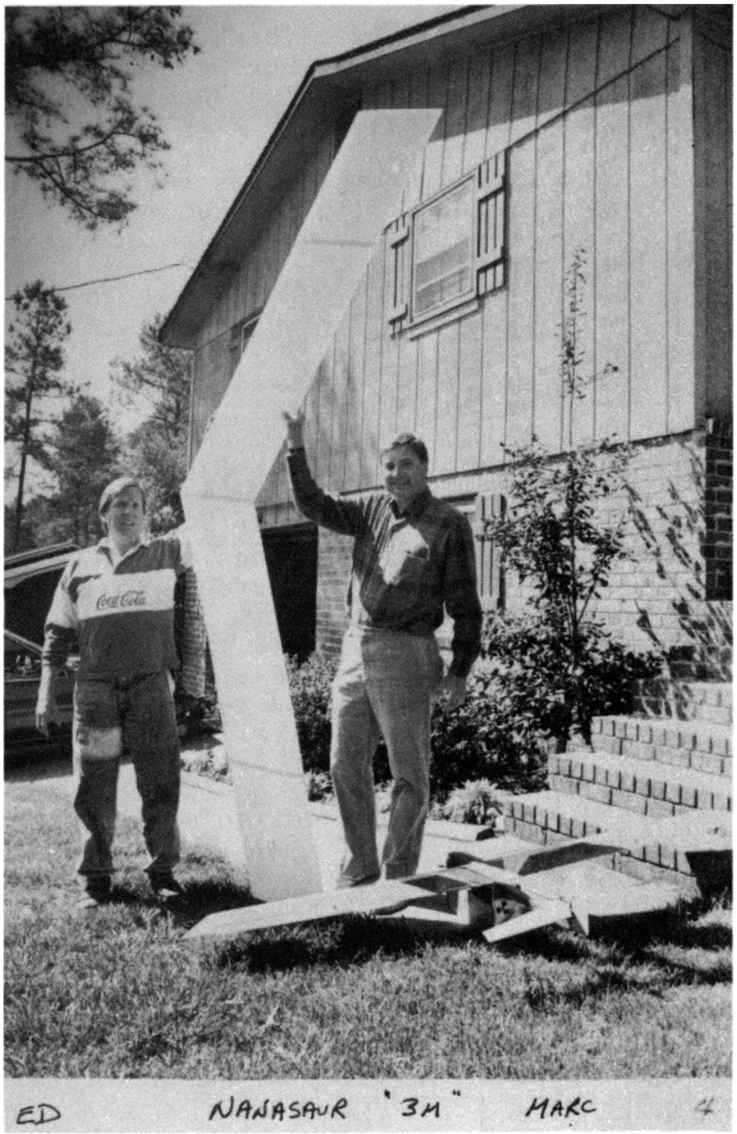
## The Nanosaur Flying Wing

by Marc Vepraskas
AMA 90549

The ancestry of the Nanosaur project can be traced to Bill and Bunny Kuhlman's articles, "On the 'Wing," in RC Soaring Digest. I have always been fascinated by 'wings. In 1975 I built the RCM (RC Modeler) Standard Plank and in 1979 the RCM Windfreak, both plank designs. In 1989 I built the Klingberg two meter 'wing. Normally I fly a straight wing Sagitta 2M. I wanted to build my own 'wing design with the features $B^2$ (Bill and Bunny) discussed. The design of the Nanosaur Project utilizes all that I have learned up to June 1990. I had to freeze the design at some point and start building!

The inspiration to design was started by reading "Winged Wonders," a book on the Northrop N9M project. The N9M was a 60 foot span 1/3 scale flying model of the XB-35 bomber project of the 1940's. The author, Mr. Wooldridge, covered the complete story of the flying wings. Another book which helped me was "Faszination Nurflugel," a German book on the development of flying wing models up to 1988. Together, and after reading and looking at all the pictures, I was hooked and Nanosaur was born.

Design started in February 1990 with a letter to $B^2$ asking for advice. I needed a source to plot the new Eppler 222 -230 series of airfoils, specifically designed for flying wings. These airfoils exhibit a very small center of pressure movement as angle of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attack is changed. The use of the Eppler airfoils is important to limit the pitch sensitivity on a flying wing. I found the airfoils in Chuck Anderson's airfoil program and ordered the IBM version of the software. $B^2$ advised I use the E 222 at the root and the E 230 at the tip with 3 degrees of negative twist (T.E. raised) for thermal flying. I decided to use the E 222 for the root, transitioning to the E 226 at mid semi-span and then to the E 230 at the tip.

In researching articles on 'wings I came across a British White Sheet magazine of the Spring of 1986 (#36). One of the articles was by Reinhard Werner who stated "Flying wing designers should think big! The greater our wing chord and area, the greater are our chances to escape Reynolds number trouble and effect a wing loading adequate to conditions of minimum sinking speed." I chose 13.5" for my chord and 122" as my span as I would otherwise have trouble transporting the wing in my van!

Nanosaur was designed to be an open class thermal flying sailplane. The wing span is 122.5" with a constant chord wing of 13.5". The constant chord was used to help stability and reduce the twist required. The negative side of the constant chord is the roll rate is degraded slightly as more weight is on the tips. The wings are swept back 20 degrees and winglets are used at the tips. The winglets block the aft 75% of the wing tip. The winglets are designed to help reduce tip stalls and aid in visibility.

In order to design the rest of the wing I needed to determine the approximate CG position to help lay out the components. To caculate the CG the neutral point of the wing first must be found. After the NP is found the CG is 5% of the root chord ahead of the NP. The NP is the aerodynamic center of the wing. The NP is calculated as the mathematical addition of the leading edge sweep back distance at 1/2 of the semi-span and 25% of the wing chord. Where the two points add up is the NP. On Nanosaur this calculates as

$$\tan 20^{\circ} \times 30'' + (0.25 \times 13.5'')$$

$$= 0.3639 \times 30'' + (13.5'' / 4) = 14.3''$$

The neutral point (NP) is thus 14.3" back from the L.E. at the root. The CG is located 5% ahead of the NP or 13.5" back. My flying experience so far has the CG 12" back! My 3 degrees of twist possibly makes the wing overly stable, dictating a more forward CG.

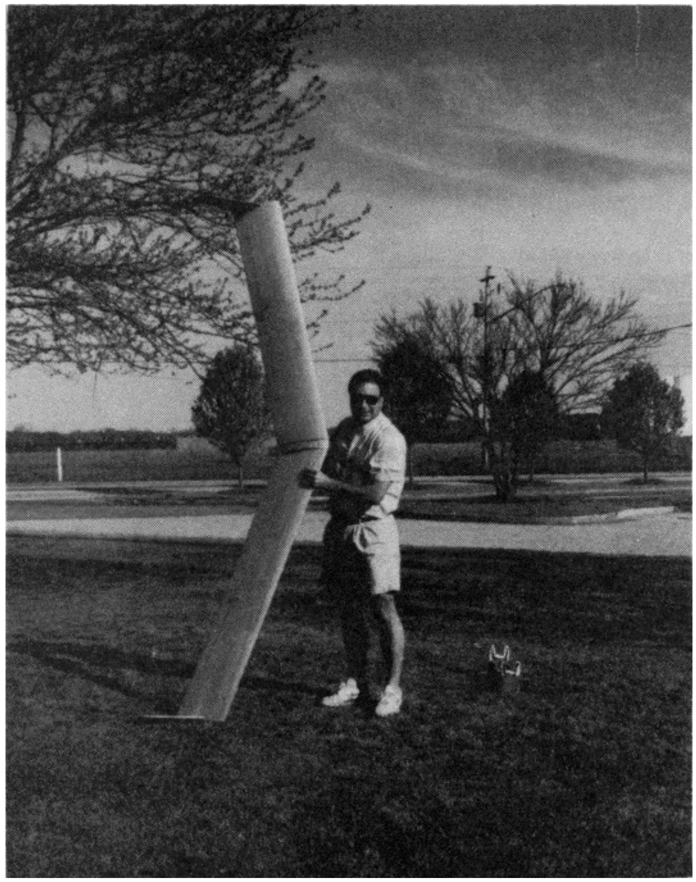
The wing's specifications are as follows:

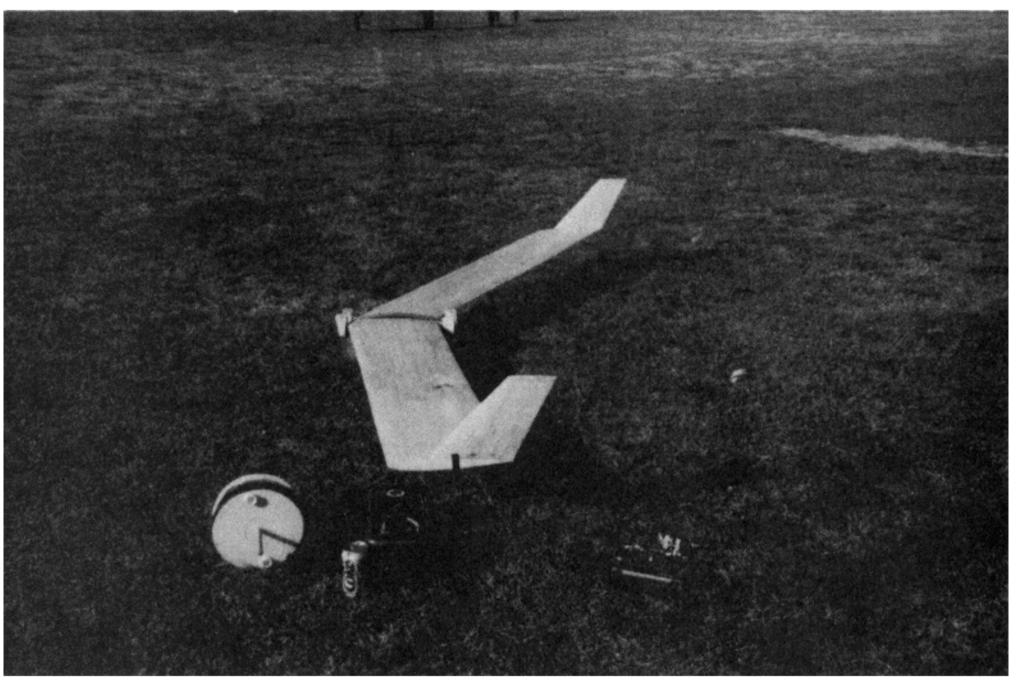
1 - Wing span of 122.5"
2 - Wing area of 1620 sq in (11.74 sq ft)
3 - Weight is 84 oz with CG at 12" back from the L.E.
4 - Wing loading is 7.6 oz/sq ft

The wing is shaped with foam cores and covered with 1/16" balsa. The balsa works well but is costly and requires hours of sanding. The cores were divided into two 30" panels 2" thick by 16" wide. A total of four panels were cut with the 20 degree sweep angle. Templates were made of the airfoils E 222, E 226, E 230 and cores cut out with a hot wire. The cores were cut to match the centerline of the three airfoils to allow the gluing of two panels into one wing half. I used the top and bottom of the foam blanks to "vacuum bag" the wing to "bed" shape. I bonded the 1/16" balsa skin to the cores with epoxy glue. The important point to remember is that with the 20 degrees of sweep the cores have to be cut with the airfoils placed in the direction of flight, not perpendicular to the leading edge!

The only control surfaces are elevons controlled by their own servo in the wing, located 7 inches ahead of the elevon. The elevons are 20% of the wing chord or 2.75" wide and 26" long. I used heavy 1/4 scale type pin hinges, five per elevon. The elevon ends 3" from the tip to allow the wing structure to hold the winglet. The servo is a standard Airtronics type with a 36" long lead running out the wing at the root 1.5" back from the leading edge.

The antenna tube is a 1/8" plastic tube running at mid-chord out the right wing 32". No radio problems or range problems have been seen. My radio is the excellent Airtronics Module SP7 on FM channel 38.





The wing joiner system is one of the keys to the wing's simplicity. Since the wing is over 1.5" thick I wanted to use two large diameter joiners. I used a joiner set perpendicular to the centerline at 37% and 75% of wing chord. The forward joiner is 12" long and the rear joiner is 24" long. Both joiners are 3/8" thickwall, stainless aluminum tubing. The wing rods are the next size of aluminum and 12" and 24" long. To help seat the two aluminum tubes in the white foam, which is weak in compression, I replaced 2" of white foam with blue foam at the two locations, 12" and 24" long. Blue foam is better for compression loading but weighs more.

The end result is the wing is rock steady on launch with no flutter problems. Each finished wing half weighs 28 oz ready to fly. Total building time was 96 hours!

The winglets are made removable with two hardwood dowels 1/4" and 1/8" inserted into brass tubing in the wing and winglet. The winglets are toed in 2 degrees as an experiment to see if they improve performance.

On the first flights I used two tow hooks located one inch below the wing on the side of the fuselage 1.5" forward of the CG. After several flights I realized one hook on the bottom was all I needed and the Y-yoke bridle was not needed. This allowed "normal sailplane flyers" to fly on my winch or hi-start.

The first launches were on Sunday March 18th 1991 with a hi-start into a 25 knot wind! The 5 pound plus wing flew straight up! Both 12 volt winch and hi-start launches have been used. The wing goes up like my Sagitta 2M! At this time only 12 flights have been flown as CG and control throws are still being sorted out.

I am now trying different tips and winglets and tow hook positions. The main goal has been reached as (with apologies to Jack Northrop) "The Wing Will Fly!" I will keep you posted on the flight performance of the Nanosaur.

## SOME NOTES ON THE CONSTRUCTION OF A STORCH IV

Gregory Vasgerdsian of California's Bay Area is planning to have a Storch IV ready for this year's Richland Scale Fun Fly in May. Gregory has full sized plans for his model, but some questions regarding certain aspects of the design and its construction remain. As some of his questions are relevant to other designs, scale and otherwise, we thought we'd share Gregory's questions and our responses with RCSD readers.

### MOVABLE RUDDERS?

**Gregory:** "The plans show the fin and rudder construction (see Figure 1), which to me looks like the rudders should move, though the plans do not show a linkage to the rudders. Are the rudders supposed to move? How?"

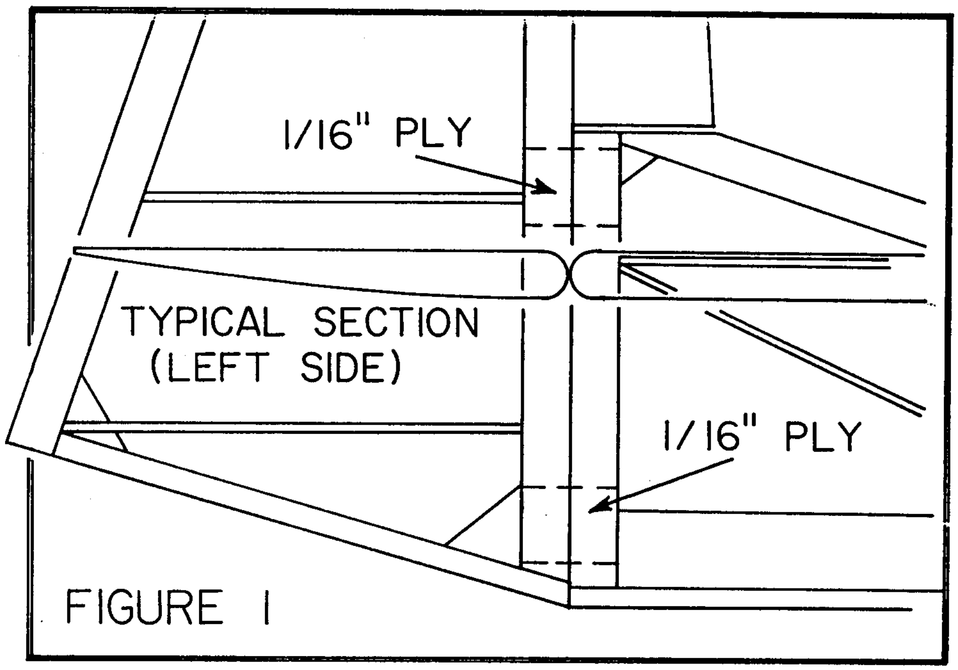
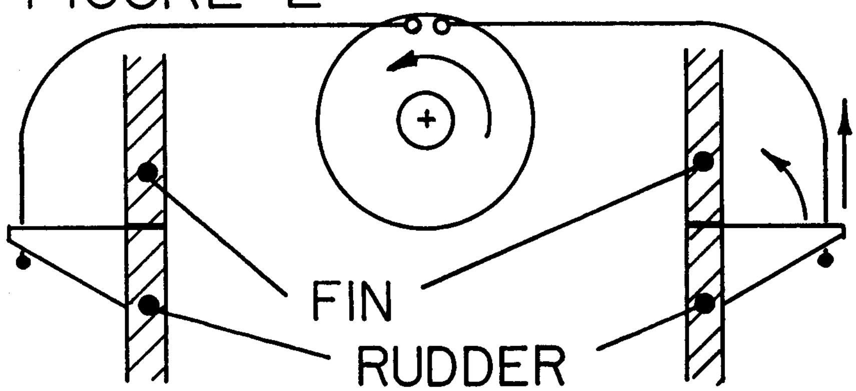


FIGURE 1

$B^2$: Yes, the rudders are supposed to move. Swept flying wings with fins and rudders at the wing tips are usually set up so the rudders swing outward only, providing a method of yaw control. This should be the case with the Storch IV model, as evidenced by the fin/rudder cross-section shown on the plans. Note the flat side of the rudder is outboard. (The cross-section for the right side is opposite to what is shown here.)

FIGURE 2




A simple method of achieving outward movement only is shown in schematic form in Figure 2. The cable, consisting of light stranded wire enclosed in a small diameter plastic sheath, needs to be free to slide through the control horn when pushed. A small diameter brass tube inserted in the plywood control horn is one way of achieving this. The small stop at the end of the cable then pulls the rudder outward as tension is applied to the cable by the servo.

A second method is to use cord, as one would to operate spoilers.

In either case, the rudder should be held against a stop by a light spring or rubber band so it remains in neutral when not being deflected by the servo.

The intent of the 1/16" plywood inserts shown on the plans is to provide a firm surface through which to install "figure 8" hinges of carpet thread, as depicted in Figure 3. The idea here is to make the hinges, then insert them in the trailing edge of the fin and leading edge of the rudder. This is an older method of hinging.

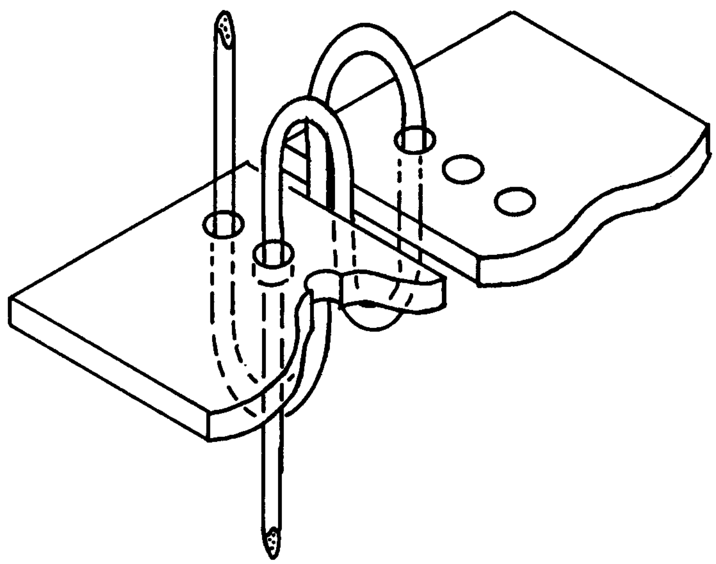


FIGURE 3

Small light conventional metal pinned nylon hinges marked for 1/2A size models can also be used, or, if using one of the heat shrink plastic films, the hinges may be made from the covering material itself. Both of these methods are far less labor intensive than the "figure 8" hinge.

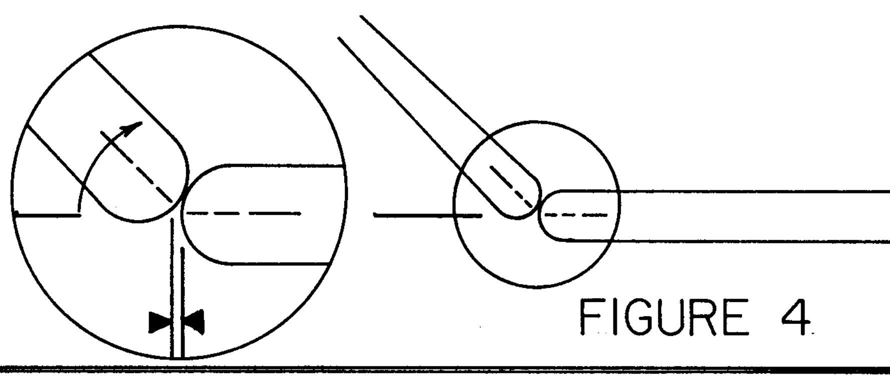


FIGURE 4

The edge contours of the fin and rudder shown on the plans may make it difficult for a hinge of any type to work properly. The underlying problem is shown in Figure 4. The two edges try to rotate apart when the surface is deflected, and this puts a strain on the hinge. We recommend a change to one of the contours shown in Figure 5 and 6. The latter is easiest to build, particularly if using the covering material as a hinge, and has the best appearance; it is also the strongest.

FIGURE 5

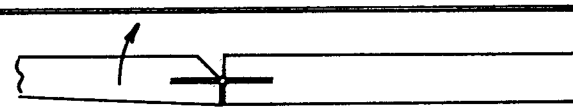
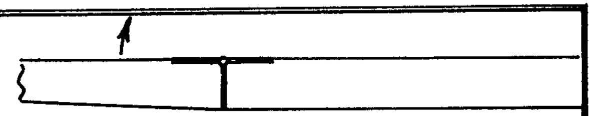


FIGURE 6



ELEVON CONTROL SYSTEM

**Gregory:** "The plans show one servo (located in the wing root) to operate each elevon, as I've drawn in (see Figure 7). Since I'm not too familiar with flying wings, I'm not quite sure what will give this model the best control. Use elevons for up and down and the rudders for left and right... Elevons mixed elevator and aileron? (I don't have a radio that will mix this, and a mechanical mixer for this function would be a hassle since the wing will be a two piecer.)"

$B^2$: We would not rely on the rudders alone to bank and turn the 'ship, as the rudders will generate rotation on the yaw axis only, and any banking will come as a result of sideslip. There really needs to be some method of roll control.

The term "elevon" is a combination of the words "elevator" and "aileron." The two elevons thus control both pitch and roll, and these surfaces operate as both elevators and ailerons. With elevons and the rudders as described previously, control will be through

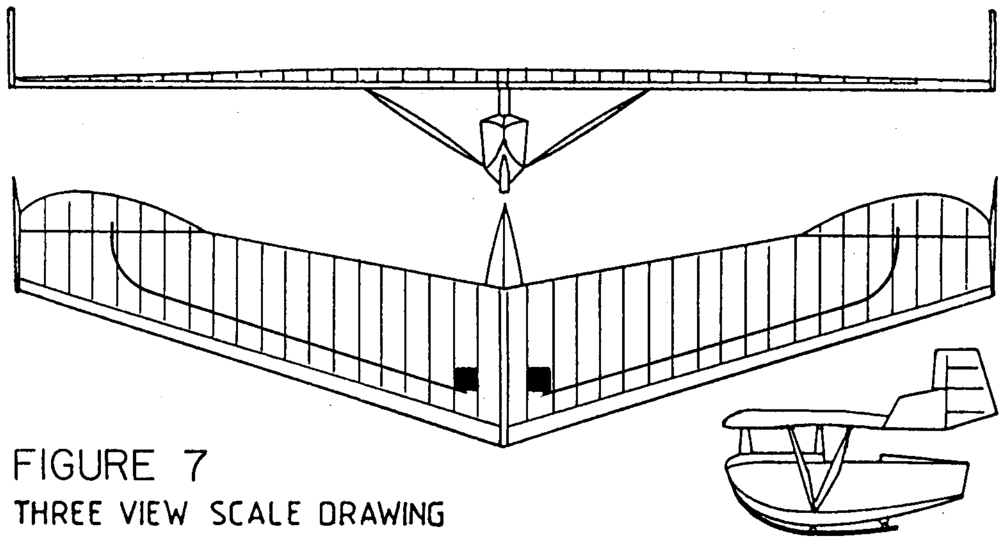


FIGURE 7
THREE VIEW SCALE DRAWING

all three axes. We would recommend this type control system for the Storch IV even if it were not so stated on the plans.

A mechanical linkage would be a complicated affair due to the two piece wing, but there are several solutions to the problem of getting two functions from one control surface:

(1) Use an electronic mixer, like the Christy Mixer (available from Ace R/C for about $35), which can mix any two functions. These mixers plug into the receiver, and the two servos then plug into the mixer. We have not used one of these, but from reports they do work well. Total servo throw as available from one channel is reduced to 50% of normal. The only way to get the left elevon to go to full deflection, then, is to give full "up" elevator and full "left" aileron. Make sure the linkage geometry provides sufficient throw.

With the Storch IV's large fuselage and generous wing thickness, placement of an electronic mixer within the airframe should not be a concern. Hook up the mixer to the aileron and elevator plug on the receiver, the rudder servo to rudder. This will give the controls a feel similar to that of a conventional tailed aircraft.

(2) Rather than purchasing a computer radio which can directly mix aileron and elevator functions, see if the transmitter has both V-tail and aileron/rudder mixing capability. If it does, hook up one elevon servo to the rudder socket on the receiver, the other elevon servo to elevator, then connect the rudder servo to the receiver's aileron socket.

With a Mode 2 transmitter and V-tail and aileron/rudder mix turned on, both elevator (pitch) and aileron (roll) functions will be on the right stick, and the rudders (yaw) will be coordinated with the ailerons. The left stick will control only the roll function of the elevons and there will be no rudder coordination.

If the transmitter has V-tail mixing only, control of the elevons will be through the rudder and elevator sticks, and control of the rudders will be through the aileron stick. This setup may take some getting used to, but is entirely feasible.

(3) A final option (and one which we've never tried in flight) is to use a basic transmitter operating in Mode 2, and hold it at a 45 degree angle to the body, oriented so the elevator and aileron axes are as shown in Figure 8. The elevon servos are connected to the receiver aileron and elevator outputs, the rudder servo is connected to rudder.

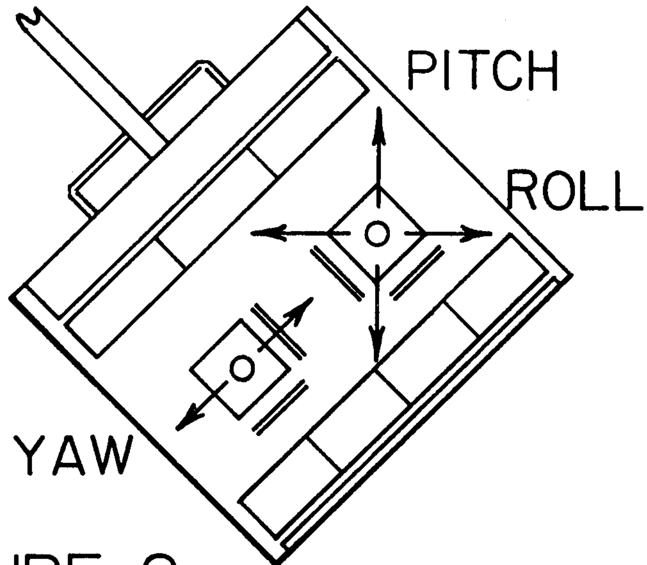



FIGURE 8

With this option, the elevons are controlled from the right stick with shifted axes, the rudders from the left stick with no axis shift. It may take some time to become accustomed to the offset pull of the centering springs on the two sticks, but this method should work well if practiced on the ground first.

## ADDITIONAL COMMENTS

We would highly suggest mounting the elevon servos in the wings so the pushrods can connect directly to the elevon control horns. Curved cables give a lot of slop, something which is quite detrimental in a swept 'wing configuration. If there is insufficient room to mount the servos at the inner edge of the elevon, go ahead and mount them as shown in Figure 7, but use a bellcrank system rather than sheathed cables.

The Storch IV should make a good slope 'ship. However, winch or hi-start launches will be impossible as the two required towhooks will need to be mounted on the lower surface of the wing rather than on the fuselage. In this location the struts will get in the way of the bridle's lines.

Gregory plans to have his Storch IV completed in March so he has some flight time on it by the time the Fun Fly comes around in May. As the Storch IV has been a favorite of ours for some time, we are quite eager to see the completed model. This is an exciting project, and we wish Gregory the best of luck in his endeavor.

Photograph from Howard Siepen

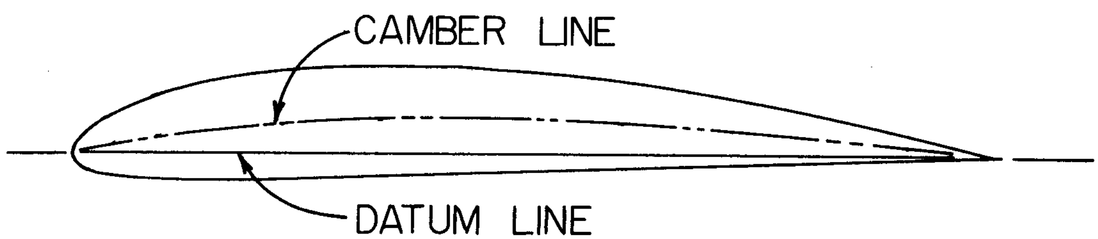
EXPERIMENTING WITH A TAILLESS, MOTORLESS PLANE

The wings are arrow-shaped, with a rudder at the tip of each wing, instead of a tail rudder.

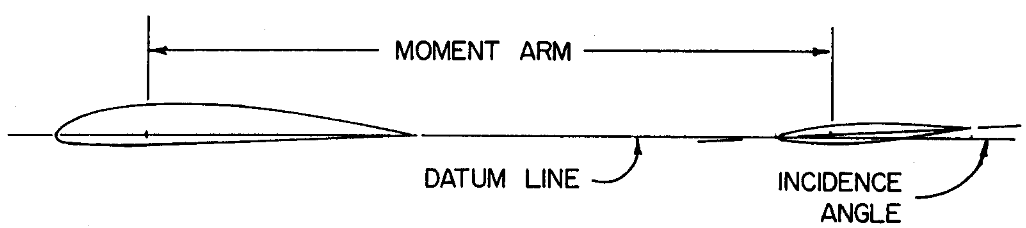
## HOW "PLANKS" FLY

One of the strangest sights imaginable is that of a plank type tailless sailplane cruising serenely overhead. How do these sailplanes, looking for all the world like boards, manage to fly? And why are they so stable?

To begin, let's look at a common and unsophisticated airfoil, the Clark Y.

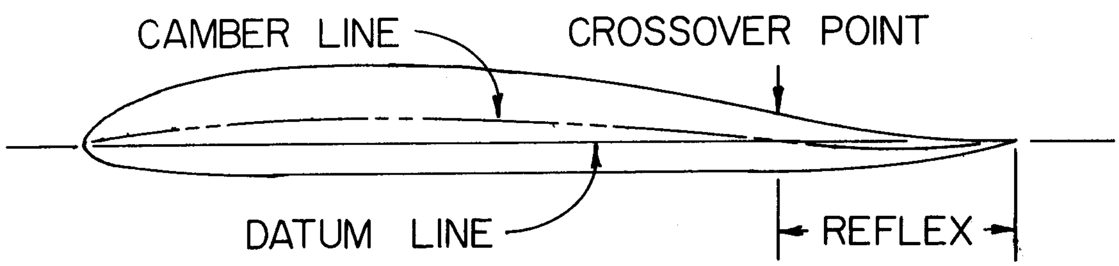



The Clark Y, in addition to being capable of providing a large amount of lift, has a negative pitching moment. Due to the shape of its camber line, shown in the drawing above, it tries to pitch forward as it moves through the air. Left alone, the Clark Y will tumble in flight unless provided with a sufficiently strong stabilizing force. This stabilizing force can be provided by a conventional horizontal tail (the stabilizer).

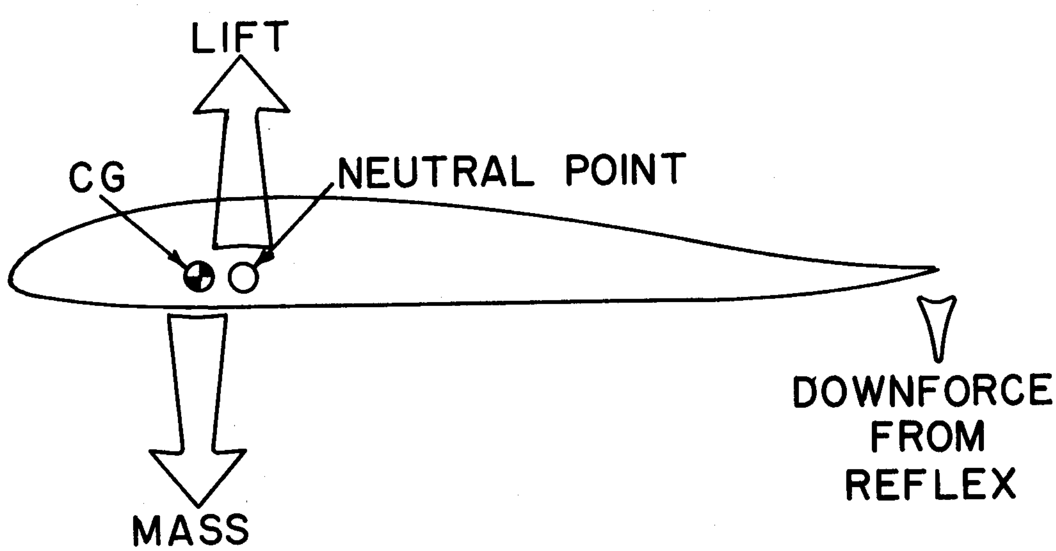



Neglecting the effects of downwash off the wing but recognizing the need to hold the wing at a positive angle to the oncoming air, the stabilizer must be set at a negative angle in relation to the wing.

If we move the stabilizer closer to the trailing edge of the wing we will find we need to make the stabilizer larger in order to produce the same stabilizing effect. Taken to the extreme, with the stabilizer trailing edge matching the wing's trailing edge, we see the following:




Notice the camber line and the fact it crosses over the mean chord line at the 75% chord point. The resulting section, the Clark YS, is an inherently stable airfoil because, contrary to what occurs with a normally cambered section, the center of pressure moves forward as the angle of attack decreases, and more rearward as it increases. Sections with greater camber will require more reflex in order to be made stable.



In trimming our plank, we place the CG ahead of the neutral point, thus producing a constant nose down force. When the CG is placed at the point where the nose down force can be exactly balanced by the aerodynamic downforce produced by the reflex in gliding flight, the airfoil is dynamically stable.

Finding the proper CG location is not difficult, it just requires some experimentation. Too far forward and the elevators will need to be trimmed to a slightly raised position; too far to the rear and the plank will be very pitch sensitive. Once the CG's proper location is discovered, however, it will remain constant.

The plank's marvelous stability is now easy to figure out. If the airfoil's speed slows, the forward CG overpowers the aerodynamic downforce of the reflex, thus increasing the speed in response. Traveling too fast, the reflex forces the leading edge up, increasing both drag and the effects of gravity.

No wonder planks make such wonderful free flight ships and R/C trainers. Reflexed sections, however, are not capable of producing large amounts of lift. The downforce which makes their stability possible is directly counter to the lift generated, and the reflex creates substantial drag. A plank's sink rate is therefore greater than we'd like to see and their speed range relatively narrow. But for some reason planks generally thermal quite well.

What can be done to improve the performance of the plank design? Reduce the amount of reflex to lower drag, increase lift, and allow a more rearward CG. The critical part of this manipulation is maintaining enough reflex to keep the CG in front of the neutral point (mean 1/4 chord line) while retaining a comfortable margin of stability. It is imperative that the CG be kept in front of the neutral point.

As planks are very easy to build perhaps some of you may wish to do some experimentation in reducing the pitching moment to a minimum. Let us know what you discover!

Suggestions for further reading...

Bates, Ken; "Windlord." The construction article for this fine performing plank was published in Model Aviation. It includes a great explanation of plank stability, both in the air and on tow.

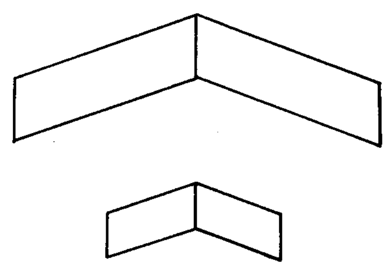
Werner, Reinhard; "Nurflugelsegler Ferngesteurt." Covers a wide variety of plank designs through 3-views and text. Also discusses moveable CG, airfoils, control systems, and other topics. German text.

Lichte, Dipl. Ing. Martin; "Nurflugel-modelle." An explanation of tailless aircraft stability and how it can be achieved. Presents a simple method of estimating airfoil pitching moments, with examples. German text.

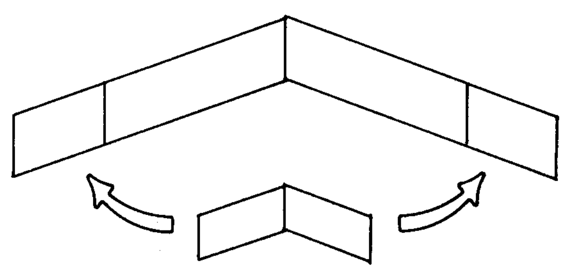
## HOW SWEPT 'WINGS FLY

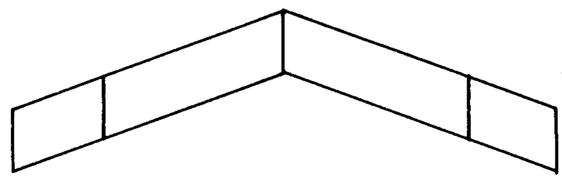
There are at least two formulae available to assist in determining the geometric twist required for swept 'wing pitch stability. A basic knowledge of how swept 'wing pitch stability is achieved is helpful in understanding the workings of these formulae.

It is probably best to think of a swept 'wing as a highly modified conventional tailed aircraft. A conventional sailplane requires a horizontal stabilizer of a particular size, given the pitching moment of the wing airfoil and the moment arm. By increasing the stabilizer's area we can move it closer to the wing while keeping the incidence angles constant.



By simply moving the horizontal stabilizer halves to the wing tips we come up with a tailless planform.





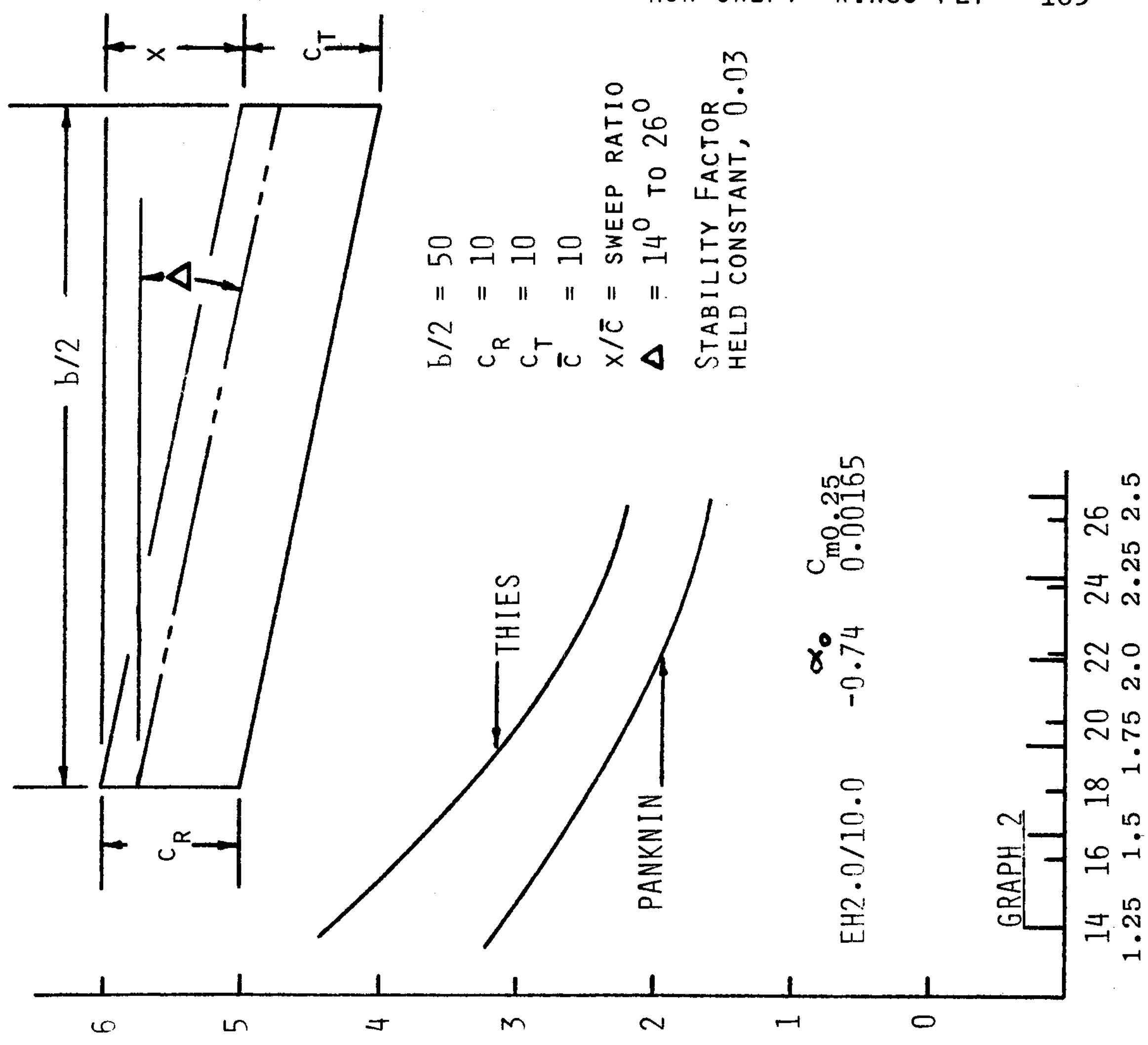
What's nice about this design is there is no downwash to adversely affect the stabilizer. On the negative side, however, the size of the "horizontal stabilizer" had to be increased due to the shorter moment arm.

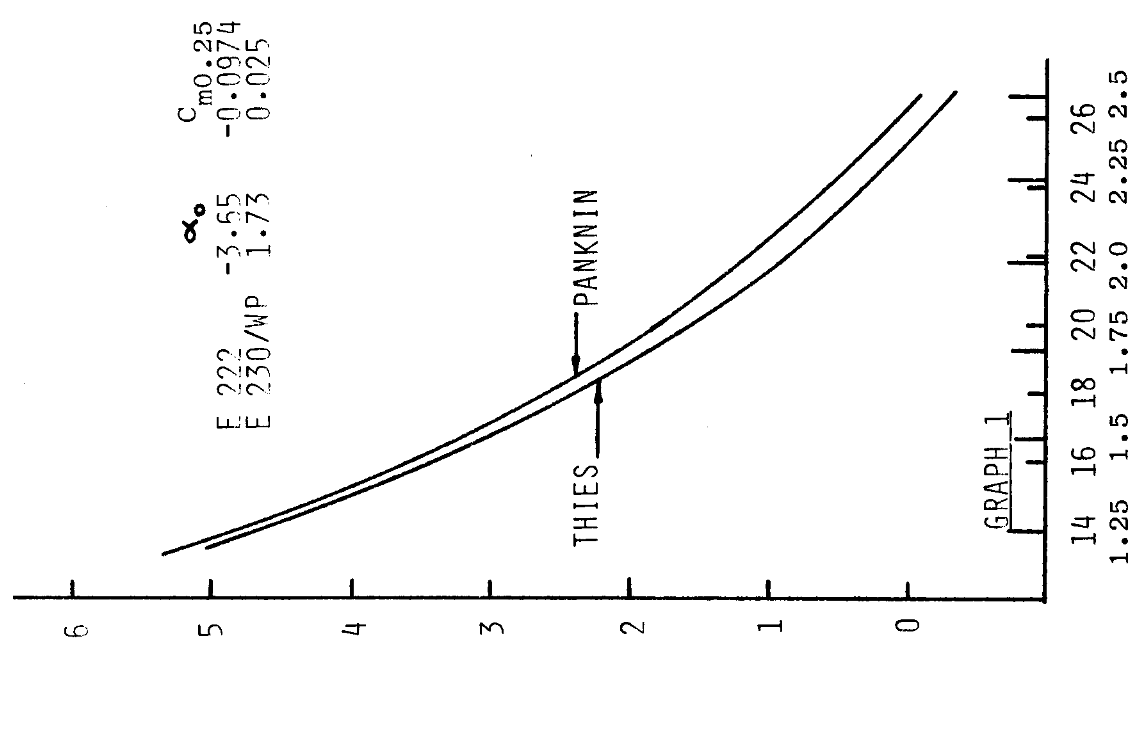
For a conventional sailplane, there are four ways of compensating for a larger negative pitching moment. A more negative angle can be applied to the horizontal stabilizer, the airfoil of the stabilizer can be changed to produce more of a down force, the stabilizer can be made larger, or the tail moment can be increased.

Projecting to swept 'wings, we would again anticipate finding that as the pitching moment of the root section became more negative a larger downforce would need to be applied at the wing tips.

Such is exactly the case, and four things can be done. First, we can retain the same tip section and build in more washout (trailing edge up) to obtain a larger down force; second, we can keep the twist the same but change the tip section to one more capable of producing the required down force; third, if the wing is highly tapered, we can reduce the taper and thus effectively increase the area of the stabilizing wing tips; fourth, we can increase the sweep angle, and hence the moment, while maintaining both the washout and original wingtip airfoil section. The trick is to pick the method which increases drag the least.

The graphs on the next page depict data for two swept wings of variable geometry. Graph 1 shows the twist required for various sweep angles when using the Eppler 222 as the root section and the Eppler 230 for the tip. Graph 2 shows the twist required for various sweep angles when using the EH2.0/10 for both root


b/2
x
$C_T$
$C_R$
Δ
b/2 = 50
$C_R$ = 10
$C_T$ = 10
$\bar{C}$ = 10
$X/\bar{C}$ = SWEEP RATIO
Δ = $14^0$ TO $26^0$
STABILITY FACTOR
HELD CONSTANT, 0.03
THIES
PANKNIN
EH2.0/10.0
α₀ -0.74
$C_{m0.25}$ 0.00165
GRAPH 2
0 1 2 3 4 5 6
14 16 18 20 22 24 26
1.25 1.5 1.75 2.0 2.25 2.5


E 222 -3.65 -0.0974
E 230/WP 1.73 0.025
α₀
$C_{m0.25}$
PANKNIN
THIES
GRAPH 1
0 1 2 3 4 5 6
14 16 18 20 22 24 26
1.25 1.5 1.75 2.0 2.25 2.5

and tip. The graphs include curves for the two popular means of determining the twist required: the Thies method and the Panknin method. Both methods have been mentioned in this column previously.

The goal when designing a swept 'wing is to reduce the twist required to about one degree. More twist, while offering greater stability, will reduce performance due to the forward CG required and the increased drag created. As well, it's very easy to create a situation where the lower surface of the wingtip is stalled. But too little twist courts full span stalling, a very dangerous occurrence.

While it may be tempting to utilize a reflexed section across the entire span, the experiences of others show this not to be a viable alternative. Best to stay with the E 222 - E 230 planform, or use an airfoil with a pitching moment very close to zero across the span. For the latter, try one of the EH series sections.

Suggestions for further reading:

Gale', Dr. Ing. Ferdinando; "Aerodynamic Design of Radioguided Sailplanes." One chapter devoted to the aerodynamics of tailless designs. Text is in both Italian and English.

Lichte, Dipl. Ing. Martin; "Nurflugel-modelle." German text devoted to tailless sailplanes and electrics. A twist formula mathematically identical to Thies' is presented.

Panknin, Dr. Walter; "Flying Rainbows." Text of Walter's presentation at the 1989 MARCS Symposium, complete with diagrams and formulae for computation of required twist. Available as part of MARCS Symposium Proceedings.

Thies, Werner; "Pfeilung - ja - aber wie gross?" Four page article explaining use of Thies' twist formula. Diagrams and graphs, step by step directions included. German text originally printed in FMT, February 1984.

# MARTIN SIMONS' PN9F

A small 3-view of Dieter Paff's PN9f appeared in The White Sheet (#7, Feb/Mar 1982; the "Flying Wings Special"), and a photograph of a PN9f constructed by Martin Simons appeared in the December 1988 issue of RCSD.

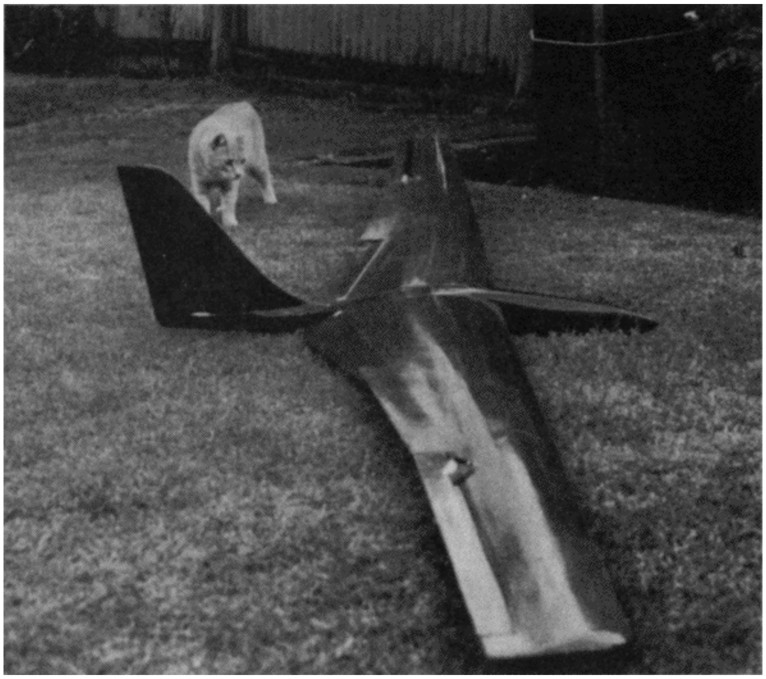
We are impressed by the design philosophy Dieter used for the PN9f, and recently asked Martin to describe the model for readers of "On the 'Wing." Martin replied with a copy of the article which set him off on this particular project (Radio Modeler, March 1980), together with some other interesting bits of information.

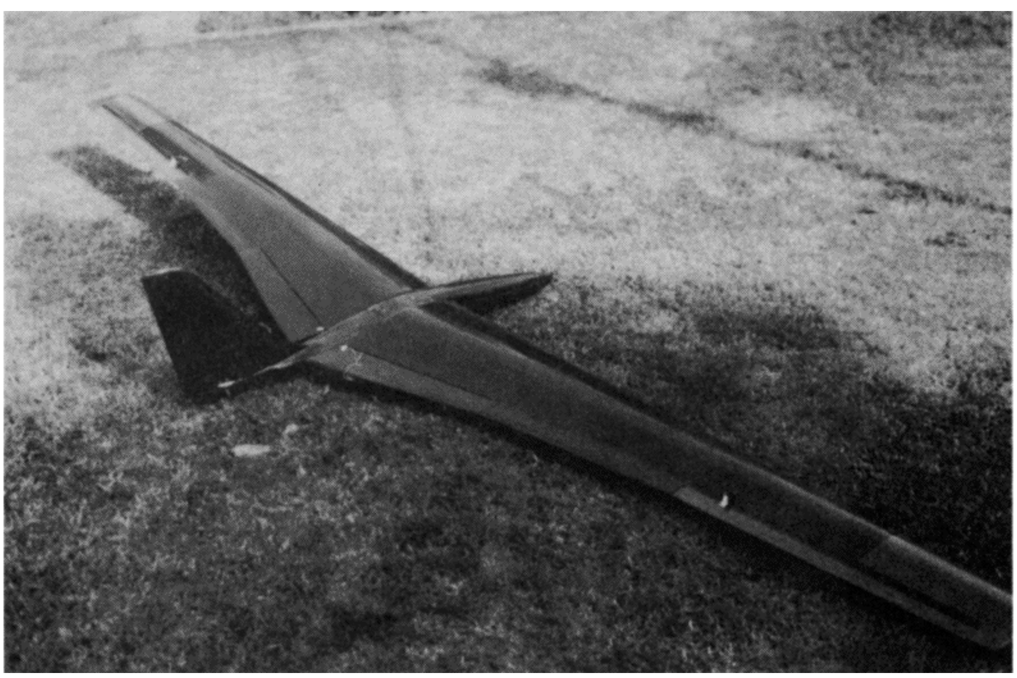
## DESIGN PHILOSOPHY

The PN9f is just one of many of Dieter Paff's models; it is actually the sixth in a series of models of a projected full sized sailplane. A wider fuselage would be incorporated in the full sized 'ship.

The PN9f was designed as one approach to high aspect ratio tailless design, and as a result has a wing geometry which is rather unique. The leading edge is straight, while the trailing edge has a double taper. This configuration was designed to provide optimum pitch stability, and elevator leverage is enhanced by having these surfaces placed well aft of the CG. The ideal elliptical lift distribution is achieved at minimum sink rate through a combination of wing geometry and airfoil selection.

Dieter's model was constructed utilizing foam core wings with obechi veneer skins. Each wing panel weighed just 17 ounces, and total weight was just under 60 ounces. Martin's model, constructed by the same methods, came out excessively heavy in comparison. He blames this on a combination of factors: less care in selection of materials, 2 mm wing skins, and a large amount of lead in the nose to achieve a proper CG location. Additionally, Martin added a braking parachute which is operated by a special





servo and is enclosed in a compartment in the rear fuselage. A complete weight breakdown for Martin's model is included at the end of this column.

## DETAILS

Several small but very important details are incorporated in the PN9f. The elevator hinge, for example, is center mounted, giving a relatively gapless fit. Additionally, the leading edge radius of the elevator is slightly larger than the trailing edge of the wing at the hinge point. This gives smoother air flow (and less drag) when the control surface is deflected. Also, since the elevators are a part of the reflexed section of the wing, and hence subject to heavy air loads even in level flight, Flettner flaps have been added. Flettner flaps are small tabs bent in the direction opposite to the reflex curve. They push the elevators upward against the downward air load, acting as an aerodynamic balance. (Several of Dieter's models were lost before this corrective action was incorporated.) Lastly, the ailerons are hinged at the upper skin, and differential is provided by the servo output wheel. This set up is very effective and allows fine adjustments without major linkage changes.

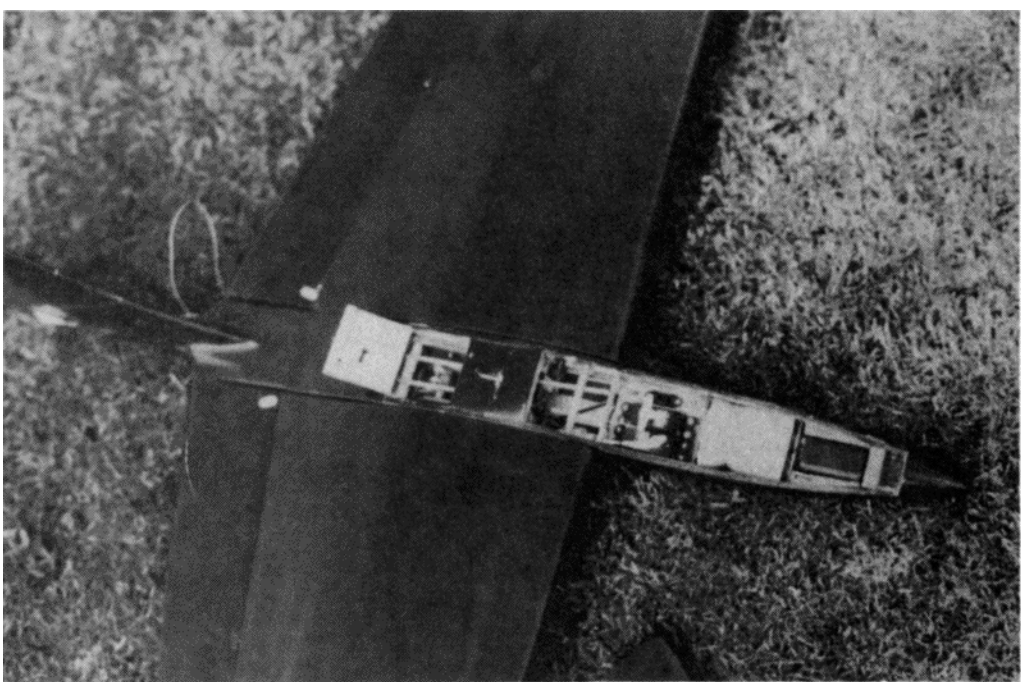
## FLYING

Martin tells us his PN9f flies very well off the slope, but due to its being overweight it has not been winch launched. Aileron differential and coupled rudder are used, and adverse yaw is in evidence if the aileron-rudder coupling is disconnected. The elevator is not sensitive, as it is with most planks, due no doubt to its location well aft of the CG. The Flettner flaps are very efficient at reducing servo loads.

Photos for this column are courtesy of Martin Simons.

PN9f WEIGHT CHART

| | | | |
|---|---|---|---|
| Wing: | cores, white foam and 'glass | 550 g | |
| | skins, 2 mm obechi | 840 g | |
| | covering, glue, wing rods | 95 g | |
| | | | 1485 g |
| Fuselage pod, bare: | | | 470 g |
| Radio: | | | 370 g |
| Lead, parachute, paint, etc.: | | | 490 g |
| TOTAL | | | 2815 g |
| Dieter Paff's model: | | | 1692 g |



## JERRY BLUMENTHAL'S "RATTLER," PLUS A SMALL IN-THE-WING MIXER

Jerry Blumenthal, a member of TWITT (The Wing Is The Thing), came up with novel methods of attaining pitch and yaw stability in his newest full sized design[1], and then fabricated an elevon mixer capable of fitting in spaces not large enough for a servo[2].

Conventional plank designs utilize a reflexed airfoil which has two inherent disadvantages: high drag and compromized lift capability. The new design, which Jerry has named "Rattler," is a single place sailplane of modified plank design which utilizes an airfoil with no reflex, and incorporates wing twist to achieve pitch stability! A look at the 3-view below shows how this is possible.

The CG is located ahead of the main portion of the wing, so the wing twist can apply the required stabilizing download. Jerry maintains the $4^{\circ}$ wing twist creates less drag and allows the wing to produce more lift in comparison to established plank planforms.

The "Rattler" is also unique in its lack of vertical surface for yaw control. The canopy fairing and wing dihedral provide sufficient lateral area behind the CG.

A side benefit of the "Rattler" planform is its simple straight spar.

In an effort to prove the design before construction of a full sized version, Jerry is building a scale model. Needing a mechanical mixer which would fit within the wing very close to the elevon, he came up with this nifty assembly. While we would prefer a mechanical arrangement where both servos pull the elevon up, there is little doubt Jerry's mechanism is both efficient and compact.

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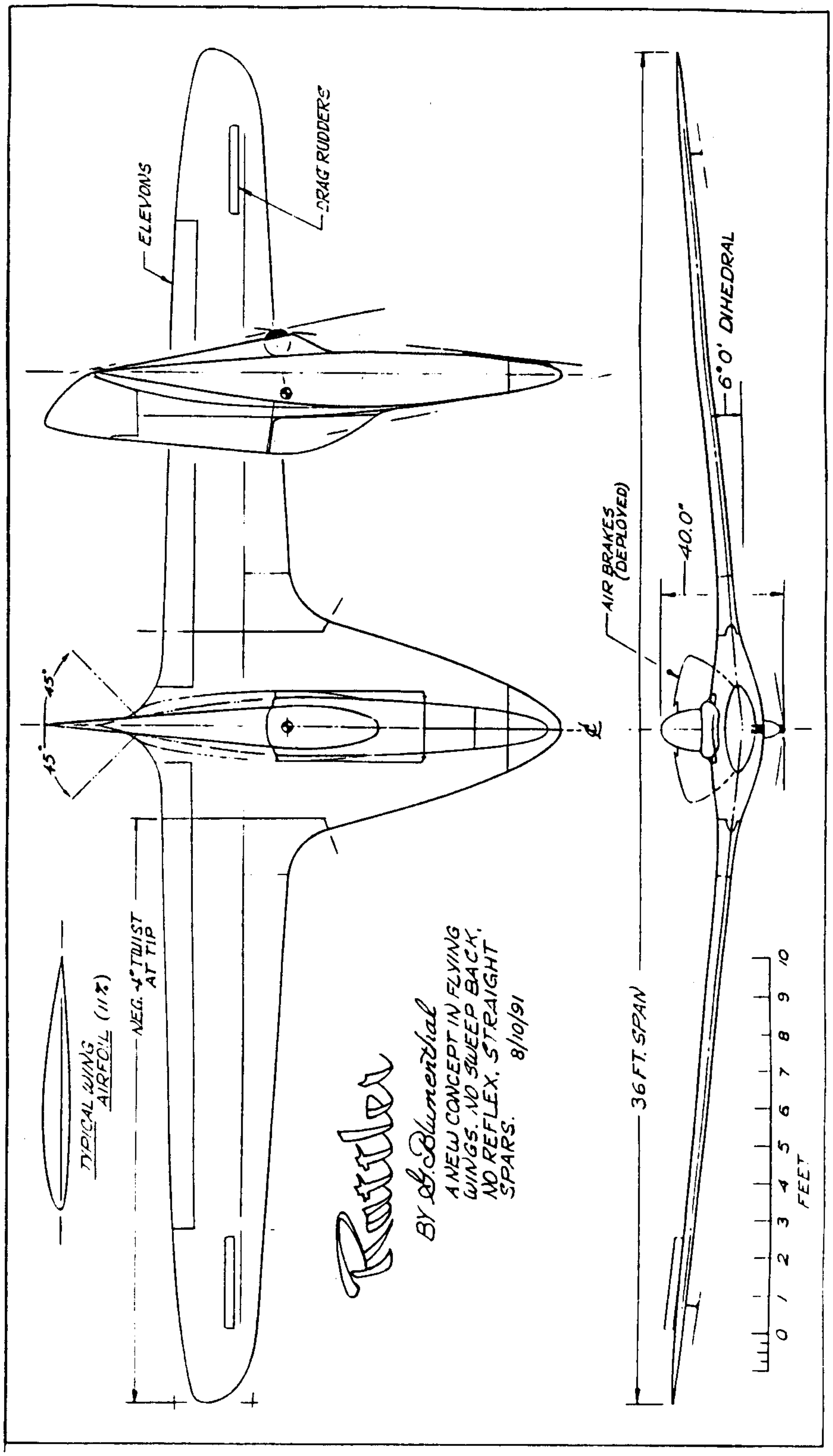
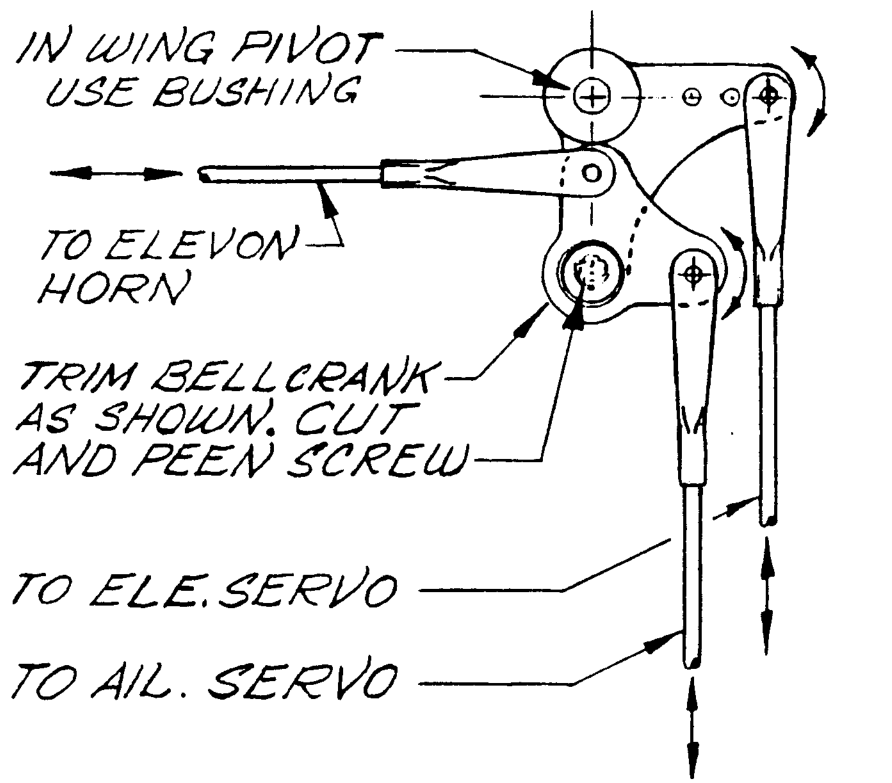
1. TWITT's <u>Newsletter</u> #63, September 1991.

2. TWITT's <u>Newsletter</u> #68, February 1992.


ELEVONS
DRAG RUDDERS
45°
45°
TYPICAL WING AIRFOIL (11%)
NEG. 4° TWIST AT TIP
Rattler
BY G. Blumenthal
A NEW CONCEPT IN FLYING WINGS. NO SWEEP BACK, NO REFLEX. STRAIGHT SPARS. 8/10/91
AIR BRAKES (DEPLOYED)
40.0°
6°0' DIHEDRAL
36 FT. SPAN
0 1 2 3 4 5 6 7 8 9 10
FEET




THIN IN-WING MIXER

USE DU-BRO BELLCRANKS
& BUSHINGS. ONE UNIT IN
EACH WING. MOUNT FIRMLY.

## AILERON DIFFERENTIAL; SOME POSSIBLE EFFECTS ON PERFORMANCE

Turning a sailplane should be a simple thing to do, right? Well, it should be, but it isn't. Several aerodynamic quirks get in the way of achieving automatic smooth coordinated turns. In this column we'll explore these quirks as they apply to both tailed and tailless designs, and give some suggestions for improving matters.

To begin, there are three types of drag which affect a sailplane in flight. First there is friction drag, created as the air moves along the surface of the model. It is friction drag which slows the air next to the aircraft surface, rapidly building a thick boundary layer. The second type of drag is form drag, caused by the changes in pressure over the skin as the air flows across it. The third and last form of drag occurs any time lift is generated. This induced drag or vortex drag is created by any lifting surface. It is especially strong at the end of the wing, where air is free to move from the lower to upper surface around the wing tip.

Friction drag and form drag are closely related and usually considered together by the term profile drag. Profile drag increases with greater velocity.

A slow flying glider must operate at a high $C_L$ to generate sufficient lift to remain in the air, while the same glider flying at a higher velocity can stay aloft while generating a lower $C_L$. Induced drag therefore increases with greater $C_L$.

There is thus an interesting relationship between profile and induced drag. At low speeds induced drag is high and profile drag is low, while at high speeds profile drag is high and induced drag is low. This is an important consideration to keep in mind.

To give a comprehensive example of profile and induced drag, consider a wire and an airfoil moving through the air together (Figure 1).

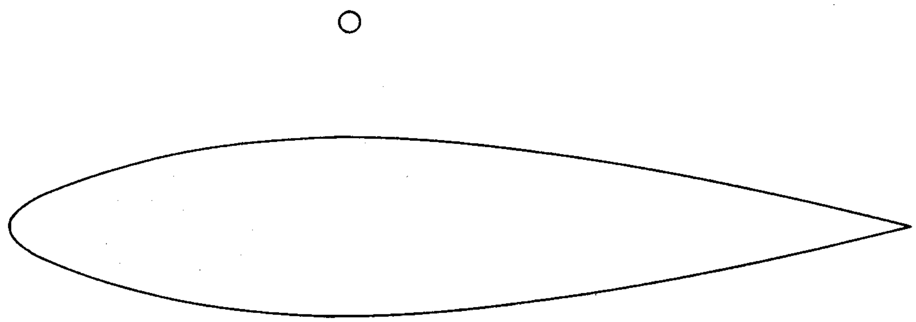


FIGURE 1

The airfoil has greater friction drag but less form drag than the wire; the airfoil's overall profile drag is less than the profile drag of the wire. This holds true even when the airfoil's thickness is up to 10 times greater than the wire's diameter. As expected, both the wire and the airfoil will experience increased profile drag as their velocity is increased.

Technically, the wire's induced drag is always zero because it is not capable of producing lift, no matter what its angle of attack. The induced drag of the airfoil, on the other hand, can change markedly as angle of attack is increased and the section begins generating lift.

Taking profile and induced drag together, you can see there are certain circumances (low speed and high $C_L$) where the airfoil's overall drag may be significantly higher than the wire's. Yet in high speed flight the airfoil would have significantly less overall drag.

Now let's get back to turning our sailplane. In turning, our sailplane rotates upon all three geometric axes: the sailplanes banks, pitches, and yaws. As evidence for this, consider the control actions required for a coordinated turn. We must bank the 'plane with ailerons (roll) and gently apply up elevator (pitch) and rudder (yaw) to bring the 'ship around. But there's a problem. We certainly don't want to fly with the fuselage yawed to the relative airflow as this is a high drag condition. Yet it seems we need to apply more rudder than necessary to get the 'ship turning in a coordinated way.

Since the rudder creates large amounts of drag as well, we want to eliminate moving this "barn door" more than is absolutely necessary. So we begin looking for reasons as to why such inordinately large rudder movement is required. This quest leads us back to aileron movement, and profile and induced drag.

Most are familiar with the Eppler 214 airfoil, and it serves as a good example for explanation. In Figures 2, 3, and 4 we see the E 214 with no aileron deflection, then downward deflection, and finally upward deflection.

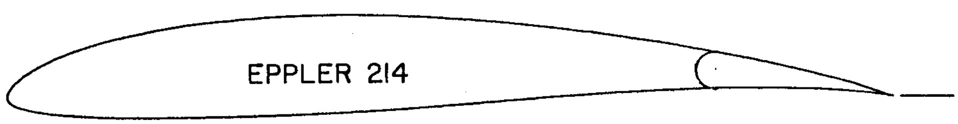



FIGURE 2

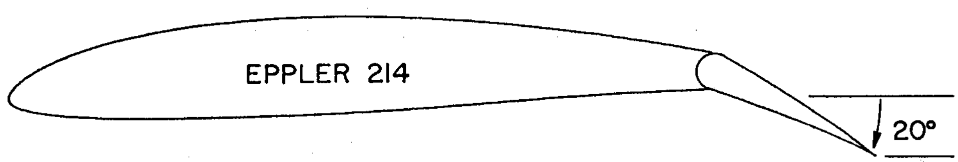



FIGURE 3

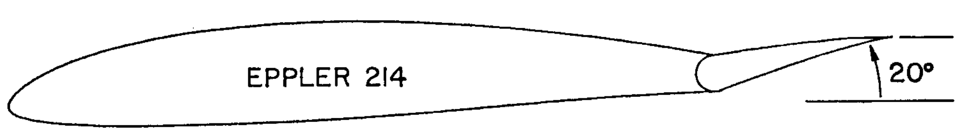



FIGURE 4

With no aileron deflection, the E 214 has a certain amount of profile drag. As the aileron is deflected downward, both profile and induced drag increase. Profile drag increases due to the hinge line and abrupt contour change, while induced drag increases due to the increased lift generated. The overall drag of the wing with aileron deflected downward is greater than the wing with no aileron deflection.

But what of the overall drag as the aileron is deflected upwards? Profile drag will again increase due to the irregularities in the surfaces, but since the wing is now generating less lift, induced drag will be reduced. The overall effect is for the rising wing (aileron down) to have more drag than the falling wing (aileron up). The sailplane therefore tends to yaw toward the rising wing, directly opposite to what we want! This action is termed adverse yaw, and it takes a large rudder movement to counteract it.

A common solution to the dilemma of adverse yaw has been to modify the control linkage so the aileron's deflection is always proportionally greater when moving upward. This so called differential is effective at inhibiting the drag increase of the rising wing through reduced downward aileron movement, while increasing the drag of the descending wing through increased upward aileron movement (Figures 5 and 6). Adverse yaw and the required large counteracting rudder movement are thus both greatly reduced, giving an overall reduction in total drag.

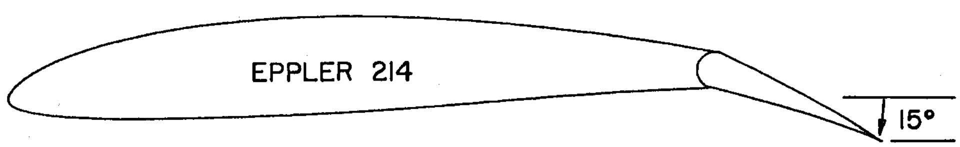



FIGURE 5

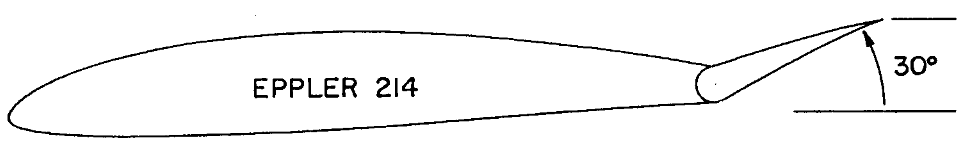


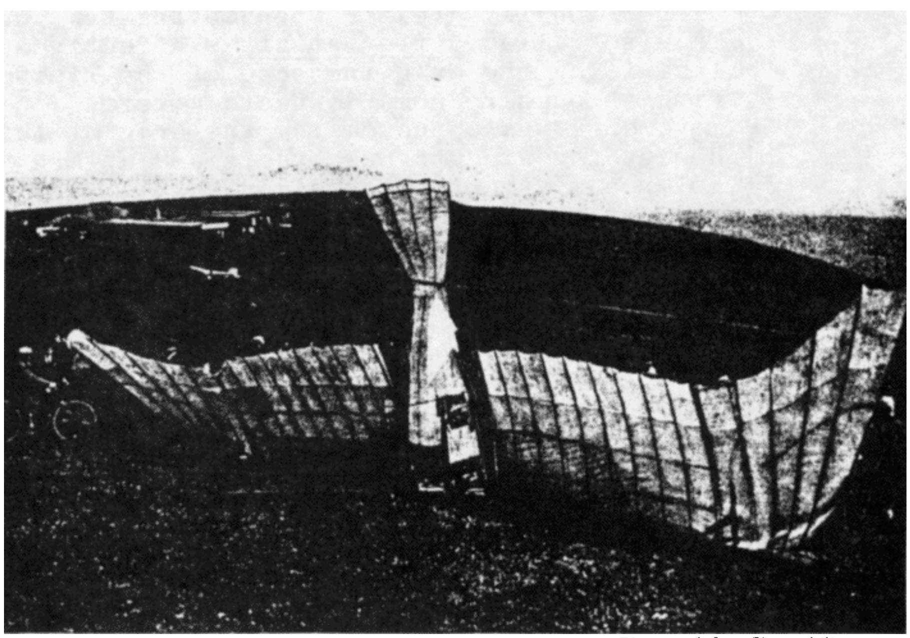

FIGURE 6

There has been a tendency among tailless enthusiasts to set up their swept 'wings with differential in the aileron function, just as with their tailed 'ships. It is our opinion this is an incorrect action, and there are two reasons for our making this statement.

Since the elevons, combining aileron and elevator functions, are behind the CG, the first thing which comes to mind is the obvious change in pitch forces which results from aileron function differential. This is because the upward moving elevon, with its greater deflection, applies a significantly larger down force than the upward force generated by the opposite aileron.

But there is another factor which is not so clearly seen - the effect of aileron movement on the induced drag of the wing tips.

On a swept wing tailless, the wing tips are applying a down force on the aircraft structure during flight. This is directly opposite to what is happening at the wing tip of a conventional sailplane. When thinking about the wing tip's induced drag, we must therefore visualize an inverted airfoil.



Photograph from Howard Siepen

PROOF THAT MAN STILL HAS MUCH TO LEARN FROM BIRDS ABOUT FLYING

Men shape their planes like birds and soar in imitation of them, but tailspins, sideslips, and crashes, unknown to birds, are inseparable from man's adventures in an element not his own, be he ever so skillful.

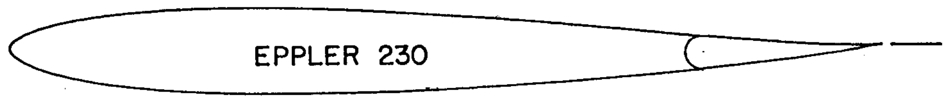



FIGURE 7

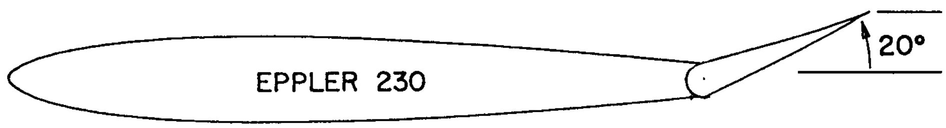



FIGURE 8

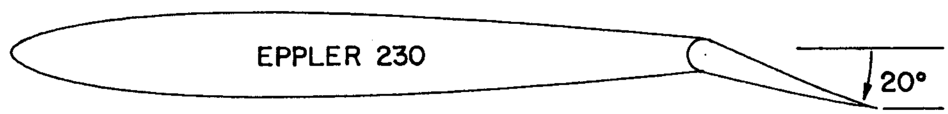



FIGURE 9

Looking at Figure 7, note the shape of the airfoil; such reflexed sections are commonly used on swept wing tailless. These sections, looking very much like inverted normally cambered sections, do not begin developing upward lift until their angle of attack is substantially positive. The wing tip's induced drag is thus related to its downward lift. This means an upward deflected aileron near the wing tip of a swept wing tailless (Figure 8) is producing more induced drag than the same aileron deflected an equal amount downwards (Figure 9)! Adverse yaw should therefore not exist, and aileron function differential will do nothing but harm in this situation.

In the case of a plank design, the wing tips are not generating a downward lifting force. Rather, the entire wing uses a reflexed section. (See Figure 10 for a typical example.) While the reflex produces the downward stabilizing force necessary for flight, the airfoil itself produces a relatively strong upward lifting force.

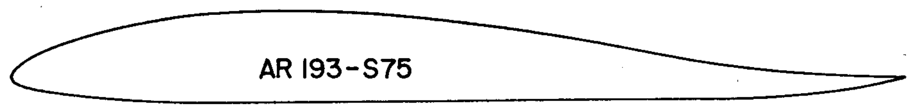



FIGURE 10

Raising one elevon therefore increases profile drag over and above the drag ordinarily created by the section's reflex, but induced drag will decrease because of the overall reduction in lift. How these two forces balance out is dependent upon control surface deflection angle and specific airfoil. Aileron function differential may therefore be needed in some circumstances, but watch for a pitch up as aileron function is applied.

As an example, Jim Marske's Pioneer II-D (schematically shown in Figure 11) utilizes 2:1 aileron differential. Since the quarter chord line sweeps forward, however, the ailerons are so close to the CG their deflection does not affect pitch significantly. In plank designs with no quarter chord sweep (Figure 12) or slightly rearward sweep (Figure 13), the ailerons will be proportionally more distant from the CG, and pitch will be more greatly affected as the moment gets larger.

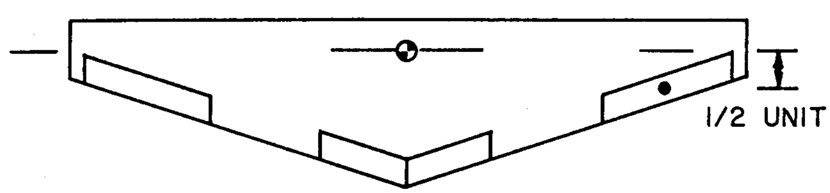



FIGURE 11

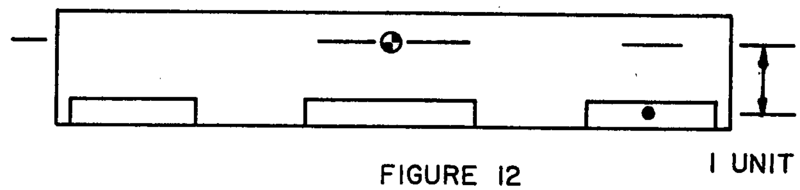



FIGURE 12

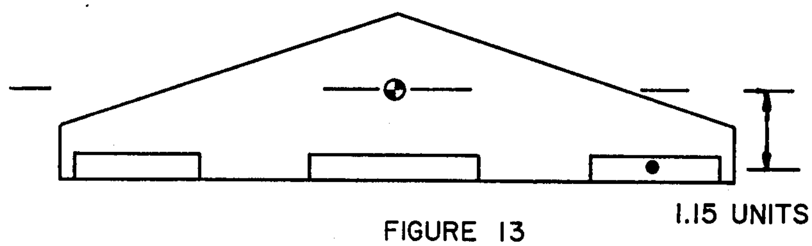



FIGURE 13

In a thermal turn, with elevons deflected slightly upward, the plank is flying with effective washout at the wing tips, while the wing root is generating near maximum lift. A centrally mounted elevator does not allow this beneficial situation to occur, and this explains why the best performing plank designs utilize elevons rather than a central elevator and outboard ailerons.

Since most flyers are now moving to computerized transmitters, with a servo driving each aircraft surface, it is becoming increasingly easy to experiment with aileron differential. If you are flying a tailless design with a computer radio, try reducing the amount of differential you are using. You might just find a substantial performance increase. We would appreciate hearing the results of your experiments!

# A MEANS OF ACHIEVING MAXIMUM DIFFERENTIAL WITH A RIGID CONTROL SYSTEM

Some swept wing tailless designs require two rudders, one on each wing tip. The idea is to have the rudder on the inside of the turn deflect outward while the opposite rudder remains motionless. A challenge is presented, however, when the rudders are connected to the same servo wheel.

In a previous column, "Some Notes on the Construction of a Storch IV," we described a system analogous to a commonly used method of deploying spoilers for accomplishing this function. Bill Kubiak, our Minnesota friend, described an alternative linkage in a recent letter to us. As Bill's suggestion is explained in terms of aileron differential, as for a conventional aircraft, we thought we'd pass on the text of the letter to RCSD readers.

"I've been reading your February 1992 column ('Construction notes for the Storch IV') and I think I have to disagree with your Figure 2. I don't like the idea of the loose string through the control horn.

"I think the loose string will allow the rudders to flap (or flutter). I think that all control surfaces should be controlled with rigid linkages. I think that a simple modification of the linkage used for 2:1 differential aileron movement would work OK.

"Figure 1 shows the usual setup for equal aileron deflection. Both push rods come off a common point on the servo wheel.

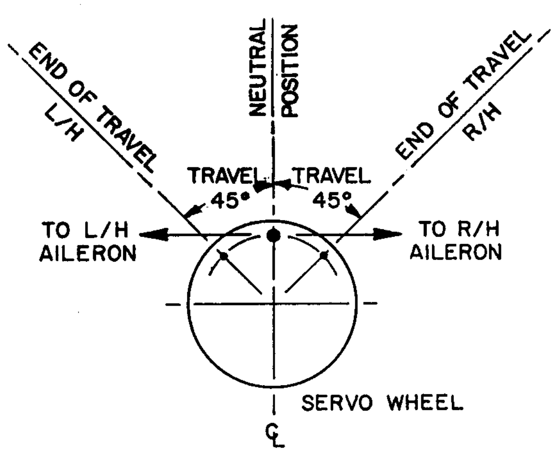



FIGURE 1

"For a 2:1 differential movement the servo wheel has two pivot points, one for each aileron, as shown in Figure 2. Each is located 39° off the common center.

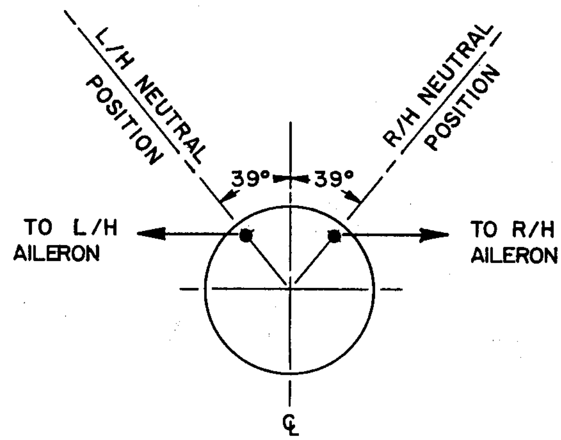



FIGURE 2

"When the servo wheel turns counterclockwise the down left hand aileron movement is equal to

$$\sin 84^{\circ} - \sin 39^{\circ} = .3652$$

"For clockwise motion the up L/H aileron movement is equal to

$$\sin 39^{\circ} + \sin 6^{\circ} = .7338$$

as shown in Figure 3.

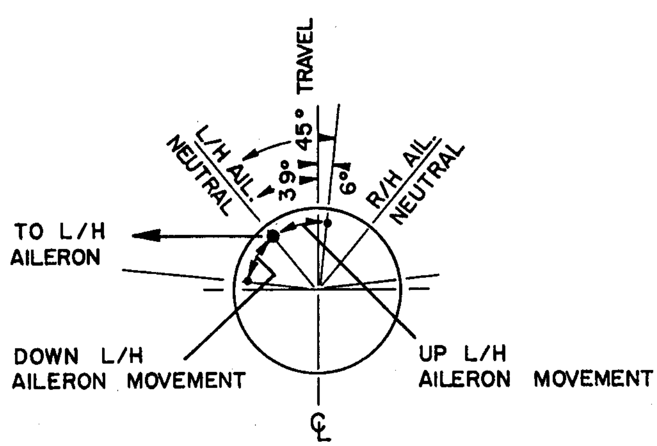



FIGURE 3

"So the ratio between up aileron movement and down aileron movement is

$$\frac{.7338}{.3652} = 2.0094$$

or 2:1.

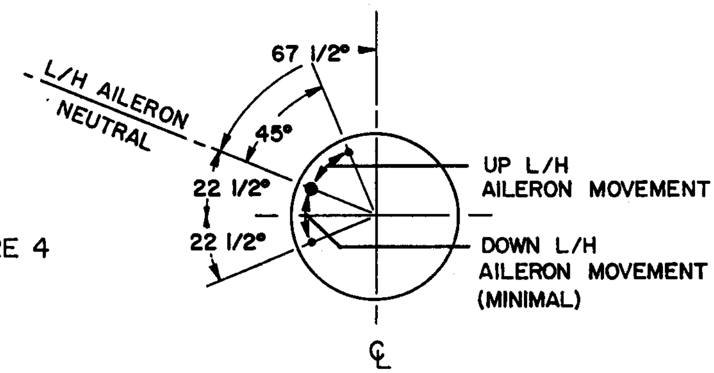



FIGURE 4

"If this method is carried to an extreme the pivot point for the L/H aileron would be moved around to 67.5° off the servo center line (see Figure 4.). When the servo wheel is turned counterclockwise the down L/H aileron movement is equal to

$$\sin 90^{\circ} - \sin 67.5^{\circ} = .0761$$

"When the servo wheel is turned clockwise the up L/H aileron movement is equal to

$$\sin 67.5^{\circ} - \sin 22.5^{\circ} = .5412$$

"And

$$\frac{.5412}{.0761} = 7.11$$

"This is the maximum aileron differential obtainable through servo wheel geometry alone.

"The down going aileron would not remain motionless while the other aileron moved up. The down going aileron would wave back and forth a little but this would be acceptable to me because the linkage would be rigid.

"Only the position of the left hand aileron linkage pivot is shown in Figures 3 and 4. The right hand aileron pivot position is symmetrically opposite to the left hand, just as for the two pivot points in the 2:1 linkage shown in Figure 2."

As stated at the beginning, the mechanics of aileron differential as described here translate equally to rudder differential as used in our applications. Bill's information is therefore helpful to designers/builders of conventional tailed aircraft, as well as to enthusiasts of tailless configurations.

Thanks, Bill!

# THE FLETTNER FLAP

One of the side effects of reflexed airfoils is a substantial down force on any control surface mounted near the trailing edge of the wing. This is caused by the reflex itself, and is indicative of the download which makes the airfoil dynamically stable once the CG is properly located.

At high speed, this force can easily overpower a servo, thus reducing the reflex. With less down force at the trailing edge of the wing, the sailplane pitches forward and steepens its glide angle. A vicious cycle then ensues, with greater speed, even larger loads on the servo, greater reduction in the reflex, and an ever steeper plummet to the earth. If the pilot realizes what's happening, remains calm, and has the intestinal fortitude to push forward on the elevator stick, an outside loop may be possible before contact with the ground occurs.

We first heard about the Flettner flap through The White Sheet "Flying Wings Special," Sean Walbank, Editor, where it was seen on Dieter Paff's PN9f design. Dieter had lost three models due to overloaded elevator servo prior to incorporating it into the design. We have since seen its use on several tailless designs, both full size and model.

The Flettner flap is a simple mechanical device which reduces the down load on the control surface by acting as an aerodynamic balance. The size of the Flettner flap should be directly related to the size of the control surface; see the diagram on the next page.

As you can see, the flap is not large. Its effect on overall drag is probably negligible. An additional bonus - it can usually be installed as a retrofit on an existing design.

Whether or not you install a Flettner flap on your design, remember to always arrange elevator servos and control linkages to PULL for UP!

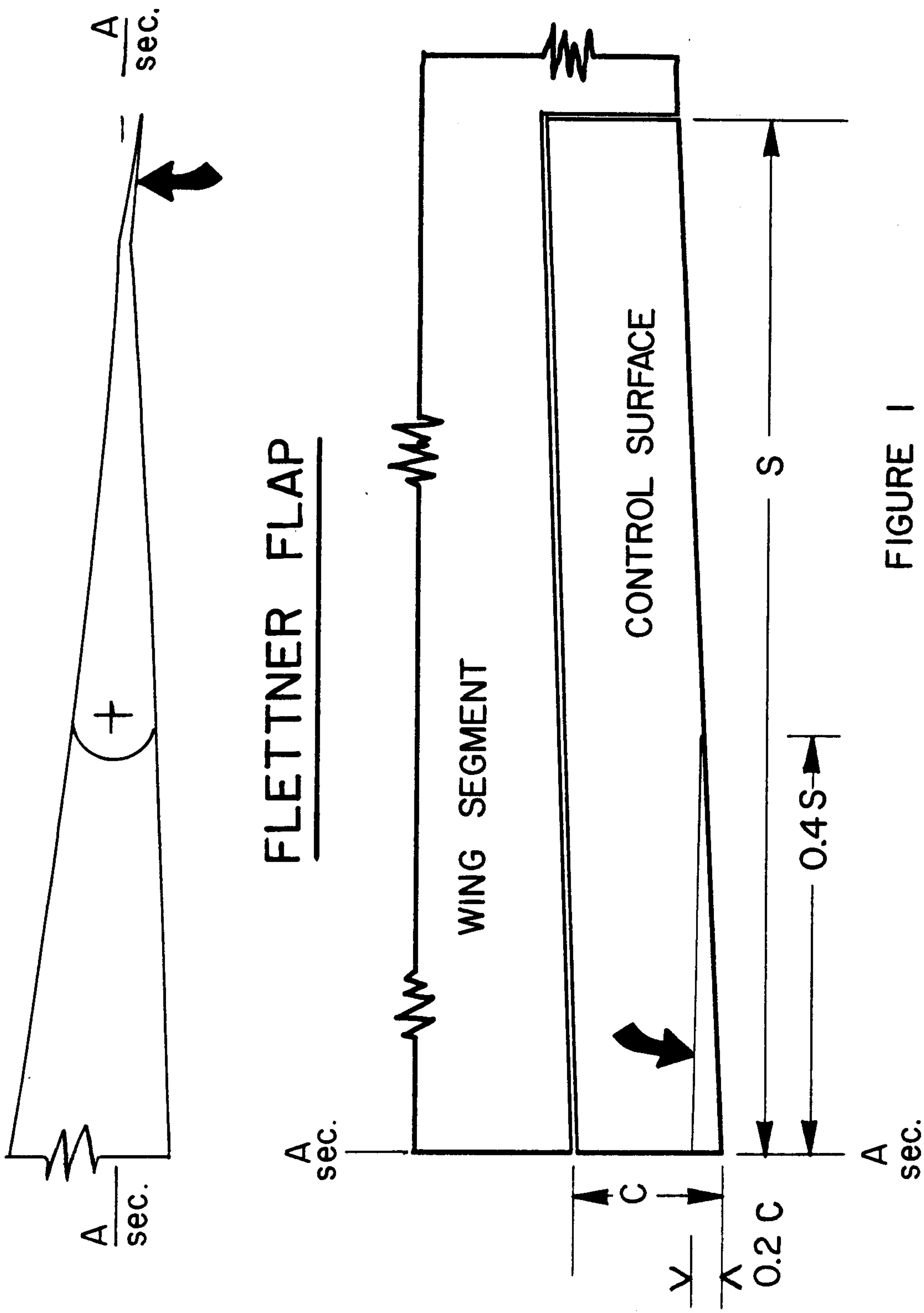

FLETTNER FLAP
WING SEGMENT
CONTROL SURFACE
S
0.4 S
C
0.2 C
A sec.
A sec.
A sec.
A sec.
+
−

FIGURE I

# DIETER PAFF'S PN11

In the June issue of RC Soaring Digest we described Dieter Paff's PN 9f model and promised to provide information on some of Dieter's other models in the future. Well, the future is now, and the model is Dieter's PN 11!

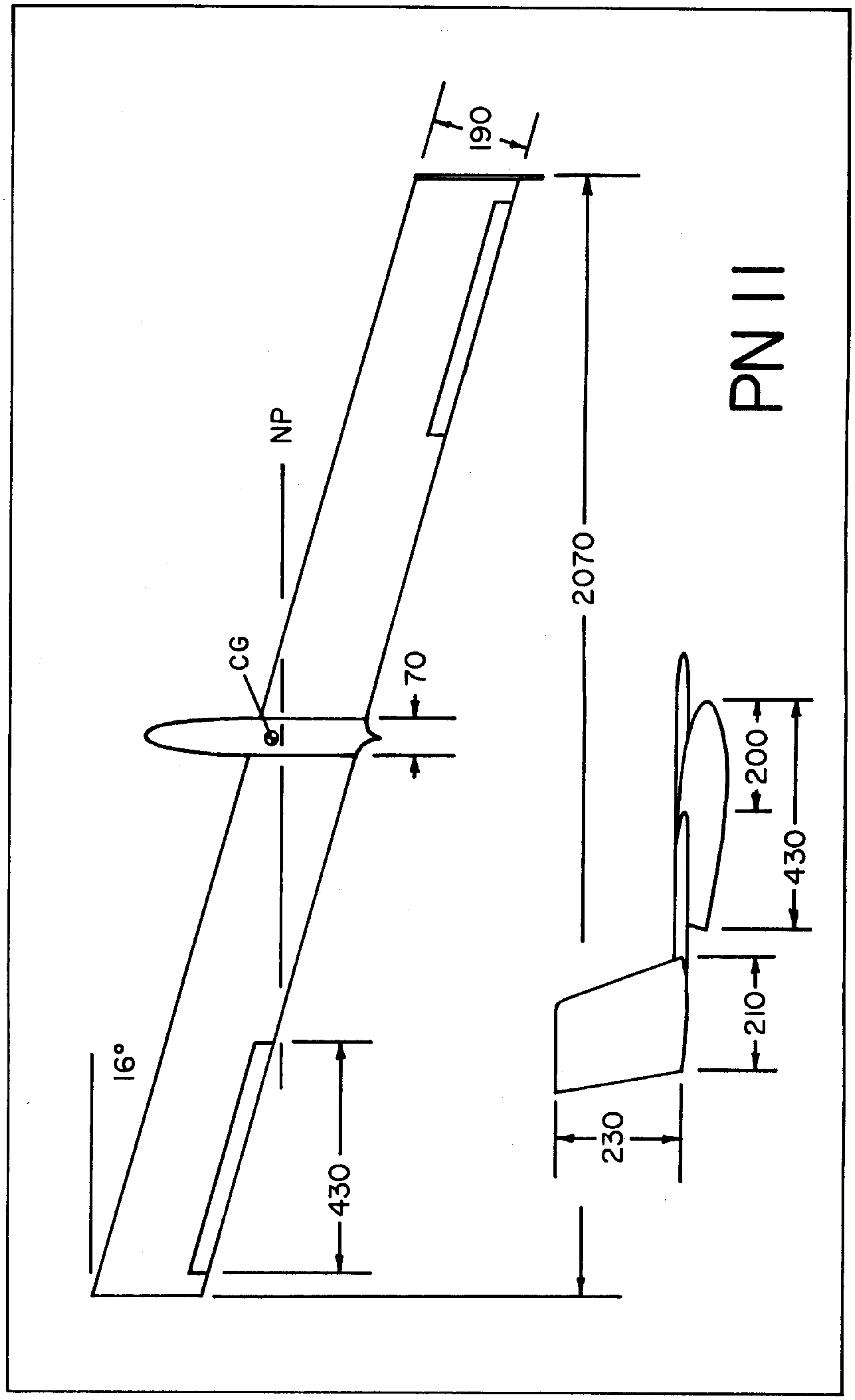
The PN 11 is unorthodox, even as tailless designs go. This planform is the result of mixing the simplicity of a constant chord plank with a swept wing. The result is reminiscent of NASA's scissor-wing X plane and some SST designs. Several small free flight gliders were constructed and tested in order to produce a viable configuration.

The PN 11 spans two meters and is perfectly at home on the slope. Control is through elevons; both move in unison for elevator, and in opposite directions for aileron. The elevon on the forward wing is very close to the CG and does not affect pitch. When both elevons are moved downward, the PN 11 dives straight ahead, as drag is equivalent for both wings. The left elevon's lack of pitch authority does show up when aileron function is called upon, however. The 'ship tends to climb slightly during right turns and drop its nose during left turns. Still, the PN 11 flies easily, and control idiosyncracies are minimal.

The single fin is mounted on the tip of the trailing wing, where it is very effective at keeping the 'ship on track. The fin's total drag apparently approximates the induced drag of the bare wing tip.

Wing construction is of the "sandwich" type. Total flying weight is under 1 Kg at 960 gm, yeilding a wing loading of 25 $gm/dm^2$, just 8 $oz/ft^2$. The wing section, designed by Dieter, is 10% thick. Despite this, the PN 11 can be very fast.

Picture this scenario... Two PN 11s, a right handed and left handed version, flying in formation above your favorite slope... Wow!


190
NP
CG
70
2070
PN 11
16°
430
200
430
210
230

# EH 2.0/12 and EH 3.0/12

In the November 1990 issue of RC Soaring Digest we described three airfoils designed by John Yost - the EH 1.0/9.0, 1.5/9.0, and 2.0/10.0. The EH 2.0/12.0 and 3.0/12.0 described this month are new additions to this series.

The first number within the EH designation denotes the percent camber, the second the percent thickness. All of the EH airfoils have very low pitching moments, essentially zero, and are ideal for swept flying wings with quarter chord sweep angles of about 20 degrees. None of the EH sections should be used on planks, as that planform requires airfoils with a substantially positive pitching moment.

These new EH sections, with their 12% thickness, can be used as root sections where a greater spar depth is needed. Some designers may consider using a thicker, higher cambered airfoil at the root and a less cambered thinner airfoil at the tip in an effort to improve efficiency. The EH 3.0/12.0 can be used where higher lift coefficients are needed. Use Table 1 as a general guide when choosing an appropriate airfoil.

Since the camber line of reflexed sections is of an "S" shape, there is a very sharp curve on the lower surface of the section near the trailing edge. Even at higher angles of attack, there is the possibility of separated flow over this area. The solution is to turbulate the airflow just before the transition point. This lower surface turbulator should be placed at about 65% chord. It is particularly important to place a turbulator in front of any control surface which deflects upwards. As with normally cambered airfoils, the performance of reflexed airfoils can be improved when operating at relatively low Reynolds numbers by installing a turbulator at about 15% on the upper surface.

We would appreciate hearing of your experiences with these new sections.

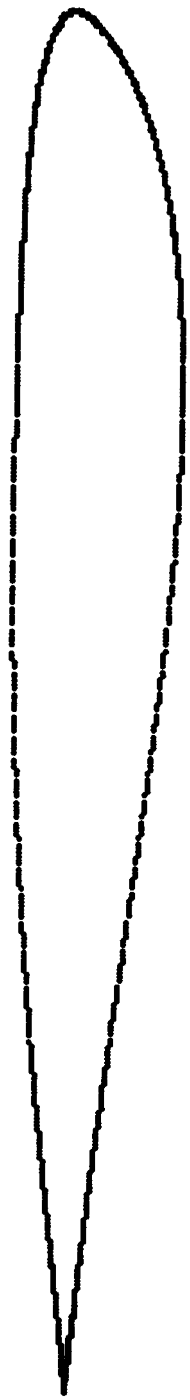
Table 1

| SECTION | USE | Cmo | $\alpha_{L=0}$ |
|---|---|---|---|
| EH 1.0/9.0 | F3B | 0.00088 | -0.37 |
| EH 1.5/9.0 | F3E and thermal duration | 0.00073 | -0.55 |
| EH 2.0/10.0 | thermal duration | 0.00165 | -0.74 |
| EH 2.0/12.0 | thermal duration and scale | 0.00165* | -0.74* |
| EH 3.0/12.0 | thermal duration and scale | 0.00165* | -1.10* |

* Approximate values from published polars.

EH 2.0/12.0

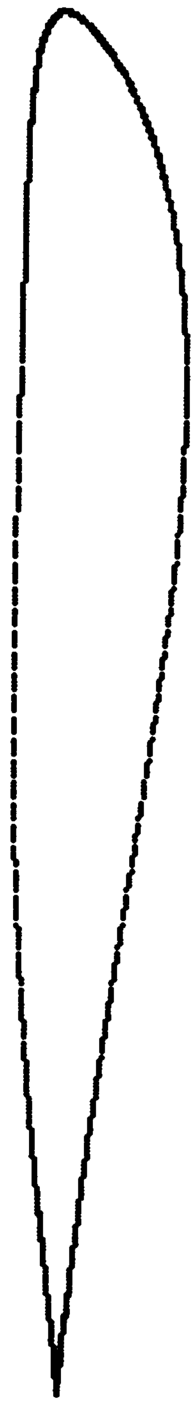
| X | Y |
|---|---|
| 100.000 | 0.000 |
| 99.901 | 0.060 |
| 99.606 | 0.024 |
| 99.114 | 0.061 |
| 98.429 | 0.121 |
| 97.553 | 0.207 |
| 96.489 | 0.319 |
| 95.241 | 0.456 |
| 93.815 | 0.617 |
| 92.216 | 0.801 |
| 90.451 | 1.009 |
| 88.526 | 1.244 |
| 86.448 | 1.503 |
| 84.227 | 1.788 |
| 81.871 | 2.096 |
| 79.389 | 2.427 |
| 76.691 | 2.779 |
| 74.088 | 3.150 |
| 71.289 | 3.537 |
| 68.406 | 3.937 |
| 65.451 | 4.346 |
| 62.435 | 4.762 |
| 59.369 | 5.178 |
| 56.267 | 5.589 |
| 53.140 | 5.990 |
| 50.000 | 6.373 |
| 46.861 | 6.731 |
| 43.733 | 7.058 |
| 40.631 | 7.346 |
| 37.566 | 7.587 |
| 34.549 | 7.774 |
| 31.594 | 7.901 |
| 28.711 | 7.962 |
| 25.912 | 7.952 |
| 23.209 | 7.869 |
| 20.611 | 7.709 |
| 18.129 | 7.473 |
| 15.773 | 7.162 |
| 13.552 | 6.780 |
| 11.474 | 6.332 |
| 9.549 | 5.824 |
| 7.784 | 5.266 |
| 6.185 | 4.666 |
| 4.759 | 4.035 |
| 3.511 | 3.385 |
| 2.447 | 2.728 |
| 1.571 | 2.082 |
| 0.886 | 1.470 |
| 0.394 | 0.915 |
| 0.099 | 0.427 |
| 0.000 | 0.000 |



| X | Y |
|---|---|
| 0.099 | -0.390 |
| 0.394 | -0.767 |
| 0.886 | -1.144 |
| 1.571 | -1.516 |
| 2.447 | -1.869 |
| 3.511 | -2.192 |
| 4.759 | -2.481 |
| 6.185 | -2.736 |
| 7.784 | -2.959 |
| 9.549 | -3.153 |
| 11.474 | -3.323 |
| 13.552 | -3.470 |
| 15.773 | -3.599 |
| 18.129 | -3.711 |
| 20.611 | -3.809 |
| 23.209 | -3.894 |
| 25.912 | -3.967 |
| 28.711 | -4.028 |
| 31.594 | -4.075 |
| 34.549 | -4.109 |
| 37.566 | -4.127 |
| 40.631 | -4.128 |
| 43.733 | -4.109 |
| 46.861 | -4.069 |
| 50.000 | -4.006 |
| 53.140 | -3.919 |
| 56.267 | -3.806 |
| 59.369 | -3.669 |
| 62.435 | -3.508 |
| 65.451 | -3.324 |
| 68.406 | -3.119 |
| 71.289 | -2.897 |
| 74.088 | -2.661 |
| 76.791 | -2.416 |
| 79.389 | -2.164 |
| 81.871 | -1.912 |
| 84.227 | -1.663 |
| 86.448 | -1.423 |
| 88.526 | -1.194 |
| 90.451 | -0.980 |
| 92.216 | -0.785 |
| 93.815 | -0.609 |
| 95.241 | -0.453 |
| 96.489 | -0.318 |
| 97.553 | -0.206 |
| 98.429 | -0.121 |
| 99.114 | -0.061 |
| 99.606 | -0.024 |
| 99.901 | -0.006 |
| 100.000 | 0.000 |

EH 3.0/12.0

| X | Y |
|---|---|
| 100.000 | 0.000 |
| 99.901 | 0.060 |
| 99.606 | 0.024 |
| 99.114 | 0.061 |
| 98.429 | 0.121 |
| 97.553 | 0.207 |
| 96.489 | 0.319 |
| 95.241 | 0.457 |
| 93.815 | 0.619 |
| 92.216 | 0.805 |
| 90.451 | 1.017 |
| 88.526 | 1.256 |
| 86.448 | 1.524 |
| 84.227 | 1.819 |
| 81.871 | 2.143 |
| 79.389 | 2.493 |
| 76.691 | 2.870 |
| 74.088 | 3.272 |
| 71.289 | 3.697 |
| 68.406 | 4.141 |
| 65.451 | 4.602 |
| 62.435 | 5.075 |
| 59.369 | 5.555 |
| 56.267 | 6.035 |
| 53.140 | 6.507 |
| 50.000 | 6.964 |
| 46.861 | 7.397 |
| 43.733 | 7.795 |
| 40.631 | 8.150 |
| 37.566 | 8.452 |
| 34.549 | 8.619 |
| 31.594 | 8.858 |
| 28.711 | 8.946 |
| 25.912 | 8.949 |
| 23.209 | 8.863 |
| 20.611 | 8.684 |
| 18.129 | 8.413 |
| 15.773 | 8.053 |
| 13.552 | 7.608 |
| 11.474 | 7.084 |
| 9.549 | 6.492 |
| 7.784 | 5.843 |
| 6.185 | 5.149 |
| 4.759 | 4.035 |
| 3.511 | 3.683 |
| 2.447 | 2.942 |
| 1.571 | 2.223 |
| 0.886 | 1.551 |
| 0.394 | 0.952 |
| 0.099 | 0.437 |
| 0.000 | 0.000 |



| X | Y |
|---|---|
| 0.099 | -0.381 |
| 0.394 | -0.731 |
| 0.886 | -1.063 |
| 1.571 | -1.374 |
| 2.447 | -1.654 |
| 3.511 | -1.894 |
| 4.759 | -2.093 |
| 6.185 | -2.253 |
| 7.784 | -2.382 |
| 9.549 | -2.485 |
| 11.474 | -2.570 |
| 13.552 | -2.643 |
| 15.773 | -2.708 |
| 18.129 | -2.711 |
| 20.611 | -2.834 |
| 23.209 | -2.901 |
| 25.912 | -2.971 |
| 28.711 | -3.044 |
| 31.594 | -3.119 |
| 34.549 | -3.193 |
| 37.566 | -3.262 |
| 40.631 | -3.324 |
| 43.733 | -3.372 |
| 46.861 | -3.404 |
| 50.000 | -3.415 |
| 53.140 | -3.401 |
| 56.267 | -3.361 |
| 59.369 | -3.292 |
| 62.435 | -3.194 |
| 65.451 | -3.068 |
| 68.406 | -2.915 |
| 71.289 | -2.738 |
| 74.088 | -2.540 |
| 76.791 | -2.325 |
| 79.389 | -2.099 |
| 81.871 | -1.866 |
| 84.227 | -1.663 |
| 86.448 | -1.403 |
| 88.526 | -1.181 |
| 90.451 | -0.973 |
| 92.216 | -0.781 |
| 93.815 | -0.607 |
| 95.241 | -0.452 |
| 96.489 | -0.318 |
| 97.553 | -0.206 |
| 98.429 | -0.121 |
| 99.114 | -0.061 |
| 99.606 | -0.024 |
| 99.901 | -0.006 |
| 100.000 | 0.000 |

## TRUE GAPLESS CONTROL SURFACES

We found the following quotation in the Minutes of the second meeting of TWITT (the Wing Is The Thing), published in TWITT's Newsletter #2, July, 1986:

"Harald Buettner then demonstrated a mechanism, which he had designed and mocked-up, which he proposed as a replacement for conventional trailing edge control surfaces. The demonstrator was a short section of a fiber-reinforced-plastic wing in which the upper and lower skins were not bonded at the trailing edge. This left them free to flex and to slide against each other from the rear spar to the trailing edge, producing a smooth change in camber over that region. A torque tube anchored to the rear spar drives a belt bonded at its ends to the upper and lower skins to flex them under the pilot's control."

No doubt about it, our interest was piqued! Our letter to Harald Buettner requesting permission to share his idea with the modeling world received a quick and positive response, and we decided to build our own mock-up to determine if the system could be used with small chord, minimum thickness wings. The result of our exercise, although crude, demonstrated that such a system could be easily installed in a five inch chord Eppler 214 wing section! Control surface movement is not only effectively achieved, but the process is both beautiful and fascinating to watch.

Our method of constructing Harald's control system adds several steps and additional parts to the building of a foam core wing: the skins must be premolded to the shape of the airfoil surface as they are not supported by the foam core; the torque tube and sufficient bearings must be installed, finally, the premolded skins must be attached to the foam core, a two stage procedure. We would be most grateful for any suggestions readers may have in the way of streamlining the construction process.

After considerable thought we have come to the conclusion that the system probably cannot be retrofitted into an existing wing. The system relies upon a flexible skin of glass fiber and epoxy only; it will not work with a balsa substrate, Rohacell sandwich, etc. Aside from that, constructing a whole new wing would probably be easier than working out a retrofit.

The major considerations to be taken into account during construction are:

(1) the control surface, when completed, will not be supported by the foam core,

(2) the "belts" connecting the flexible surfaces to the torque tube must cross so that the lower rim of the torque tube is tied to the upper surface and the upper rim is tied to the lower surface, and the belts must come off the torque tube at a 90$^{o}$ angle,

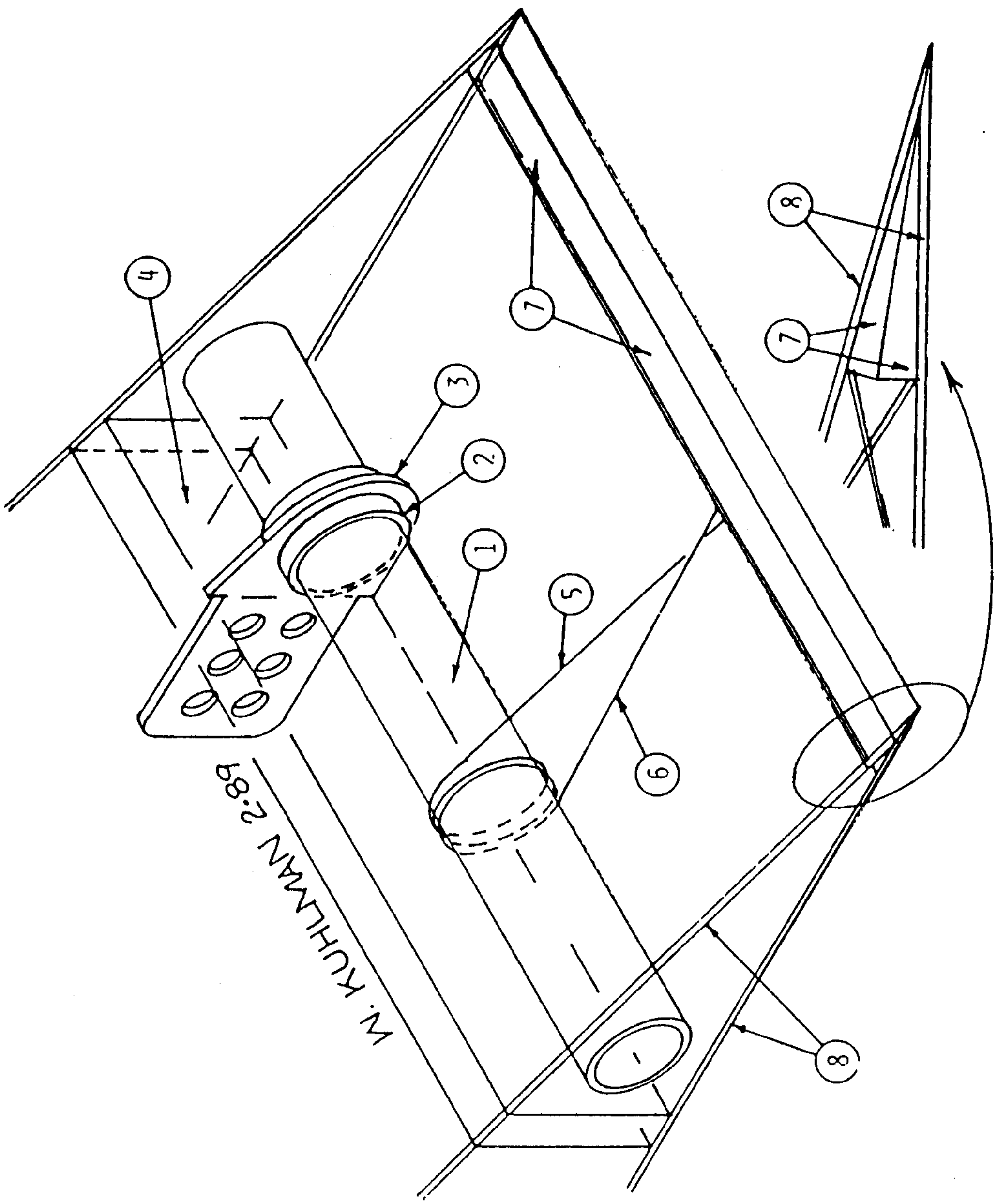
(3) flexibility, and hence control surface movement and freedom from distortion, is dependent on the weight of glass cloth used and the rigidity of the trailing edge,

(4) the trailing edge will be only as sharp as the combined thicknesses of the finished skins, and

(5) insufficient care during construction will of course result in an airfoil and control surface which do not perform well, if at all.

We highly recommend that you construct a working mock-up prior to attempting to incorporate the system in a flying model. Some of the construction is tricky (as we found out), and it's better have negative experiences on a small scale.

Experimentation, particularly with the weight of glass cloth used, will undoubtedly be necessary. As a starting point, we used a single layer of two ounce cloth for our five inch chord mock-up. Additionally, you'll have your own favorite way of connecting servo to torque tube. With some experience it is possible to design the system to incorporate tapered and swept control surfaces, along with variation of movement across the span.




1. *Torque Tube*
2. *Bearing for Torque Tube*
3. *Torque Tube and Bearing Mounting Bracket*
4. *Rear Spar/T.E. Cap*
5. *Belt to Lower Surface*
6. *Belt to Upper Surface*
7. *Plywood T.E. Strengthener and Belt Tie Down*
8. *Wing Skin of Fiberglass Cloth*

Here's the step by step procedure:

(1) Cut the foam core to be used. We used pink extruded foam for its resistence to denting, increased strength, and ease of cutting by the hot wire method. The resulting core should be of full chord and allow for the thickness of the fiberglass skins which will be applied.

(2) Cut upper and lower foam beds, making sure that they are large enough to support the trailing edge along the entire span. Take as much care making these beds as you did for the wing itself; they can be used again for another wing.

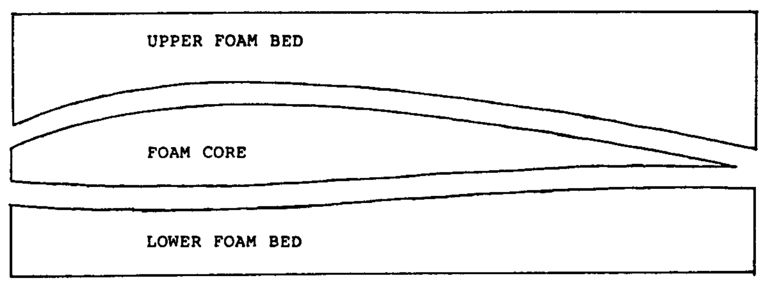



FIGURE 1

(3) Lay fiberglass cloth which has been cut to size on a sheet of mylar. Squeegee epoxy into the 'glass just as you would if creating a fiberglass skin. Use more than one layer if that is your practice.

When completed, place another layer of mylar over the 'glass and epoxy, making a sandwich.

With the wing's upper surface resting on its foam bed, place this sandwich of mylar and epoxied 'glass on the lower surface of the wing in its correct position. Now add the lower bed.

Apply weight or start up your vacuum bag.

NOTE: Since the trailing edge is so critical to excellent performance, we recommend that you do <u>not</u> attempt to 'glass the upper surface of the wing simultaneously with the lower. To do so risks deformation of the airfoil at the trailing edge due to multiple layers of mylar between the two surfaces.

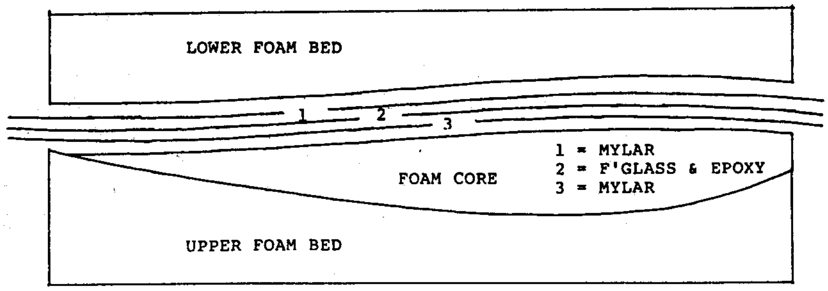



FIGURE 2

(4) After curing, remove the molded lower skin and repeat step 3 for the wing's upper skin.

(5) You now have a foam core, complete with beds, and two molded fiberglass sheets that match the contour of the airfoil over the entire chord and span.

Mark a first line on the foam core where the control surface would normally be hinged using a conventional method. Now draw another line forward of the one already drawn; the distance between them should be one half of the thickness of the airfoil as measured at the first line plus the thickness of the cap used to seal the trailing edge of the foam core. This is important, as there is very little flexing just aft of the supporting foam, and you're looking to place the center of the torque tube at the location of the conventional hinge line.

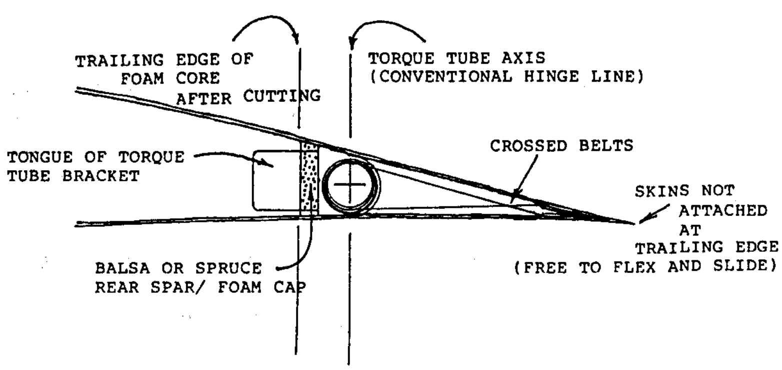



FIGURE 3

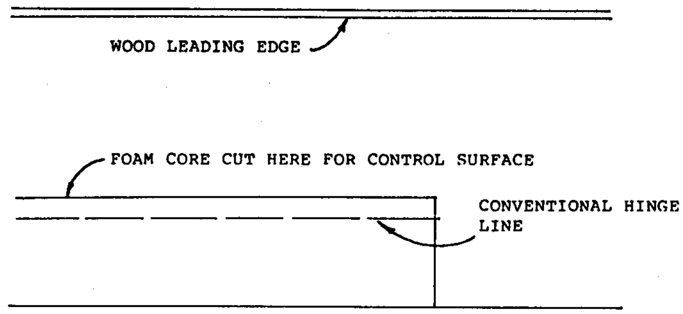



FIGURE 4

Using a straightedge, and cutting on the forward line, remove the trailing edge of the foam core where you wish the control surface to be.

(6) Install the rear spar/trailing edge seal to the foam core, followed by the torque tube and its bearings. The torque tube should be as large as possible while allowing clearance for the "belts" and the flexing skins. To assure a nonbinding mechanism, install the plywood bearings with the torque tube in place; don't forget to attach a control horn to the tube beforehand.

We found that the bearings could be cut using a short piece of sharpened tubing as a drill.

Be careful not to glue the tube to the bearings during assembly!

(7) Bond the "belts" to the torque tube with epoxy. We roughened the tube and applied a very small amount of 5 minute epoxy to carpet thread cut to lengths much longer than needed. Make sure that all of the threads are glued along a straight line on the tube's surface. After the epoxy has cured, rotate the tube until all of the epoxied points are facing the foam core's trailing edge. Temporarily lock the tube in this position.

(8) This part, and #9 that follows, takes some skill, practice, and slow cure (1 hour) epoxy! Take each end of each thread and wrap around the torque tube a full turn. The objective here is to allow the tube to make at least a half turn without placing stress

on the point at which the thread is epoxied to the tube.

Spread a thin layer of epoxy resin over that portion of the lower skin which will contact the foam core and place the skin epoxy side up on its bed. Place the foam core on its skin in the correct position. Watch the threads!

Place a thin bead of epoxy at the trailing edge of the skin and have a narrow length of sanded 1/64th inch plywood ready to bond to the skin. The plywood strip will act as both a trailing edge strengthener and as an attachment for the threads coming off the top of the torque tube. The strip should be wide enough that the flexed upper skin will not catch on it when flexed to extreme positions, yet narrow enough that the threads are attached as close to the trailing edge as possible.

NOTE: It is extremely important to sand the plywood strips to a triangle like cross section so that the trailing edge of the wing is sharp and the skins will slide against each other without binding or catching. It is also beneficial to have grooves cut into these strips which will accomodate the threads. If this is not done there will be bumps at each thread which will prevent the two skins from coming completely together.

Now pull all of the threads coming off the UPPER part of the tube across the trailing edge of the wing while keeping the threads which are coming from the lower part of the tube out of the epoxy and out of the way. Check to make sure that the threads still make a full revolution around the tube before comig off at a tangent. Lay the plywood trailing edge piece directly over the threads, trapping them. Move the threads into the precut grooves. With the torque tube still locked, pull the threads uniformly tight without distorting the skin.

Place a narrow strip of mylar over the plywood piece, then put a layer of mylar over the entire upper part of the wing, followed by the upper bed. Using weight or a vacuum bag, bond the lower skin to the foam core. Make sure that all of the threads are pulled uniformly tight during this process. The thin strip of mylar in contact with the plywood at the trailing edge should assure that there is sufficient pressure to bond plywood, threads and 'glass.

(9) Remove this assembly from the foam beds once it has cured.

Spread epoxy over the upper skin where it will attach to the foam core and place it in the upper bed. Place the nearly completed wing on the skin, positioned correctly. Temporarily weight the wing so that it will not move. Unlock the torque tube and lift the lower skin trailing edge, exposing the upper skin trailing edge. Block the skins apart so that you have access to the interior of the eventual control surface. Pull out the thread ends - these should be from the LOWER edge of the torque tube and should still complete one revolution around the tube.

Spread a thin layer of epoxy over the trailing edge of the lower surface for the bonding of the sanded and grooved plywood trailing edge strengthener. Straighten the threads, make sure they still make a full revolution around the tube before coming off at a tangent, and lay down the plywood. Move the threads into their grooves.

Remove the blocks and insert a strip of mylar between the surfaces to prevent their becoming bonded to each other. Lock the torque tube in position once more and then pull the threads uniformly tight. Place a piece of mylar over the wing.

Place the lower bed on the wing and weight or apply vacuum bag making sure that the threads are still pulled uniformly tight.

(10) When cured, remove the completed wing from the beds and remove the inserted sheet of mylar from between the two surfaces. With a razor saw, cut the control surface free.

(11) Unlock the torque tube, and... VOILA! All that's needed now is an appropriate leading edge.

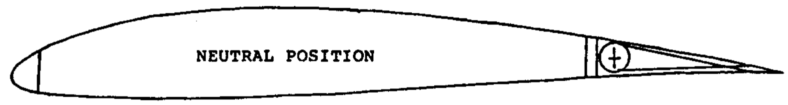



FIGURE 5A

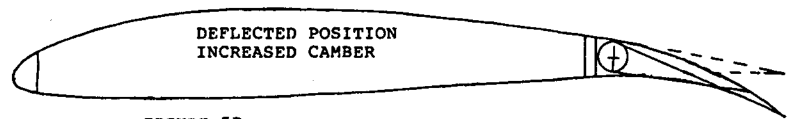



FIGURE 5B

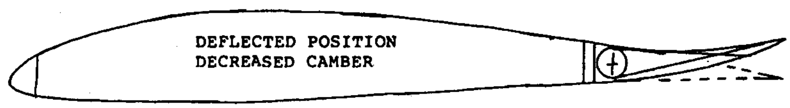



FIGURE 5C

If you're like us, you probably won't get around to putting on the leading edge right away - the control surfaces can now be flexed by rotating the torque tube and you'll be fascinated for hours on end.

As mentioned above, there are probably some improvements that can be made to the basic system. On a tapered wing, for example, the torque tube's diameter can be changed along the length of the aileron; this would provide more or less control movement at various locations along the span of the aileron.

One item that sort of "bugged" us was the open ends of the control surface. Try making a plug out of latex foam which is the same size as the open end. Held in place with a very thin coating of bathtub sealer, this sort of plug should retain a large amount of flexibility.

Many thanks are due to Harald Buettner, not only for developing this control system, but for allowing us to share it with our fellow model builders. Harald can be reached at PRECOMTEC.

TWITT's Newsletter, always filled with goodies, is available by subscription; contact TWITT (The Wing Is The Thing).

A big "thank you" is also due Jim Gray, RCSD's editor at the time of this article's publication, who, upon receiving our mock-up in the mail, immediately called us and expressed his enthusiasm and eagerness to print this information.

## THE DU 86-084/18

Flug- und Modelltechnik announced a new airfoil for conventional tailed sailplanes in its February, 1990, issue - the DU 86-084/18. While one might wonder how this airfoil works at all, work it does, and very well. Our first look at this new section triggered our memory banks into action, and we soon had a compact "family tree" assembled which outlined the underlying philosophy and aerodynamics of its design.

### EPPLER 662

The first in this tree, the Eppler 662, was included in a 1979 paper presented by Dr. Richard Eppler in which he discussed several new airfoils designed by means of his computer program. The E 662 was specifically designed for full sized sailplanes with full span flaps capable of both positive and negative deflections. Full span flaps normally pose a challenge for the aerodynamicist; Dr. Eppler designed an airfoil which could take full advantage of this configuration.

The flap, of about 20% chord, is capable of movement within a minimum $-7.5^{\circ}$ (up) to $+10.0^{\circ}$ (down) range. To understand why this section works so well, it's important to remember this point: when the flap is down the Reynolds number is rather low; when the flap is up the Reynolds number is very high. Dr. Eppler was able to utilize the hinge line to advantage during flap deflections.

With the flap positively deflected (down) the suction peak at the hinge line promotes a transition ramp which greatly improves the airflow over the aft part of the upper surface; during negative flap deflections the hinge line stabilizes the lower surface laminar boundary layer.

The theoretical polars for the E 662 appear to be excellent, but we don't know if the E 662 has ever been used on a full sized sailplane.

## HQ 35/12.29

The second airfoil in the tree, the HQ 35/12.29, was found in a 1985 paper by J.L. van Ingen and L.M.M. Boermans, both of Delft University of Technology in The Netherlands. The latter part of their paper contained the results of tests run on low Reynolds number airfoils, one of which was this section by K.H. Horstmann and A. Quast (not Helmut Quabeck, as the HQ prefix would seem to indicate). This airfoil was also designed for full sized sailplanes with full span flaps, but it has less drag than the E 662.

The HQ 35/12.29 is 12.29% thick, with a flap chord of just 13.5%. The deflection range for the flap is, at a minimum, from $-4^{\circ}$ to $+28^{\circ}$ and is to be used full span. Of interest here is the significant drag reduction achieved at all flap deflection angles with the attachment of "zig-zag" turbulators at 69% chord on the upper surface, and at 83% chord on the lower.

The concave corner present at the flap hinge leads to local separation of the turbulent boundary layer as expected, but filling and rounding the corner results in no further drag reduction than is achieved with the turbulators alone.

## DU 86-084/18

It is fairly obvious the primary subject of this article, the DU 86-084/18, is a direct descendant of the above sections, but particularly the HQ 35/12.29. The DU 86-084/18 is 8.4% thick and was specifically designed for F3B and F3E aircraft with full span flaps. (F3B and F3E in this case signify the general FAI type designations, not the multi-round competitions.)

The flap is of 18% chord and has a deflection range of at least $-5^{\circ}$ to $+15^{\circ}$. Much consideration went into the boundary layer changes taking place at various Reynolds numbers and flap deflections.

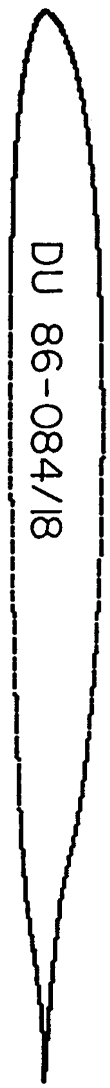
"Zig-zag" turbulators are used, just as on the HQ section; they are placed at 67% chord on the upper surface and 78% on the lower. This artificial turbulation produces a significant drag reduction.

The DU 86-084/18 was used on an F3B type aircraft which broke the previous world speed record by 20%, achieving an average 250.4 km/h (155.6 mph) - that's how well it works. (FAI rules for speed records have been changed. Lap distance has been increased, and this results in lower average speeds than previously recorded.)

As the Reynolds numbers of our models rise, we will no doubt see our airfoils become more closely allied with those of full size soaring. The DU 86-084/18 clearly shows this direction.

DU 86-084/18

| | |
|---|---|
| 100 | 0 |
| 99.88200 | .01447 |
| 99.53665 | .0583 |
| 98.99013 | .11925 |
| 98.23506 | .17817 |
| 97.25984 | .24032 |
| 96.06422 | .31488 |
| 94.65337 | .40844 |
| 93.03528 | .52965 |
| 91.2222 | .6837 |
| 89.22955 | .8769 |
| 87.06801 | 1.09809 |
| 84.72141 | 1.34217 |
| 82.17831 | 1.67666 |
| 79.56653 | 2.20332 |
| 77.03317 | 2.79601 |
| 74.53438 | 3.26522 |
| 71.9594 | 3.62654 |
| 69.28009 | 3.92896 |
| 66.51482 | 4.17247 |
| 63.67622 | 4.42331 |
| 60.77684 | 4.62555 |
| 57.82917 | 4.80102 |
| 54.84557 | 4.95081 |
| 51.83809 | 5.07531 |
| 48.81872 | 5.17501 |
| 45.79983 | 5.25045 |
| 42.79392 | 5.30151 |
| 39.81293 | 5.32781 |
| 36.86865 | 5.32933 |
| 33.97267 | 5.30581 |
| 31.13605 | 5.25702 |
| 28.36955 | 5.18325 |
| 25.68385 | 5.08479 |
| 23.08928 | 4.96201 |
| 20.59593 | 4.81538 |
| 18.2135 | 4.64516 |
| 15.95123 | 4.45172 |
| 13.81801 | 4.23513 |
| 11.82156 | 3.99464 |
| 9.96773 | 3.72991 |
| 8.26129 | 3.44198 |
| 6.7067 | 3.13251 |
| 5.30788 | 2.80381 |
| 4.0688 | 2.45893 |
| 2.9929 | 2.09987 |
| 1.33511 | 1.35292 |
| .75531 | .97171 |
| .33386 | .59511 |
| .07521 | .25174 |




| | |
|---|---|
| .00336 | -.04726 |
| .15717 | -.31004 |
| .52525 | -.57736 |
| 1.08302 | -.85296 |
| 1.83287 | -1.11716 |
| 2.76332 | -1.37678 |
| 3.87149 | -1.62443 |
| 5.15408 | -1.85711 |
| 6.60709 | -2.07293 |
| 8.22607 | -2.27012 |
| 10.00638 | -2.44734 |
| 11.94246 | -2.60385 |
| 14.02826 | -2.73971 |
| 16.2565 | -2.85504 |
| 18.61926 | -2.94976 |
| 21.10864 | -3.02423 |
| 23.71603 | -3.0796 |
| 26.43152 | -3.11721 |
| 29.24452 | -3.13827 |
| 32.14399 | -3.14417 |
| 35.11781 | -3.13606 |
| 38.15422 | -3.11475 |
| 41.24124 | -3.08161 |
| 44.36585 | -3.03845 |
| 47.51444 | -2.9864 |
| 50.67352 | -2.92648 |
| 53.8289 | -2.85963 |
| 56.96652 | -2.78628 |
| 60.07223 | -2.70638 |
| 63.13174 | -2.62052 |
| 66.13135 | -2.5263 |
| 69.05754 | -2.4225 |
| 71.89732 | -2.30875 |
| 74.63852 | -2.18080 |
| 77.26988 | -2.03913 |
| 79.78017 | -1.87273 |
| 82.15536 | -1.67216 |
| 84.4124 | -1.41497 |
| 86.5874 | -1.10373 |
| 88.68765 | -.7996 |
| 90.68719 | -.53887 |
| 92.55052 | -.33242 |
| 94.24745 | -.17859 |
| 95.75055 | -.08113 |
| 97.0405 | -.02878 |
| 98.10382 | -.0029 |
| 98.93387 | .00425 |
| 99.528 | .0034 |
| 99.87941 | .00059 |
| 100 | 0 |

## SUPPLEMENTARY INFORMATION TO "ON THE 'WING..." #24

### Eppler 662

NASA Conference Publication 2085
Science and Technology of Low Speed and Motorless Flight, Part I
Proceedings of a symposium held at NASA Langley Research Center, Hampton VA, and sponsored by NASA Langley and the Soaring Society of America
March 29-30, 1979
Perry W. Hanson, Editor
National Technical Information Service #N79-23889-23903
5285 Port Royal Road
Springfield VA 22161

N79-23896 Some New Airfoils, by Dr. Richard Eppler, University of Stuttgart, Stuttgart, West Germany

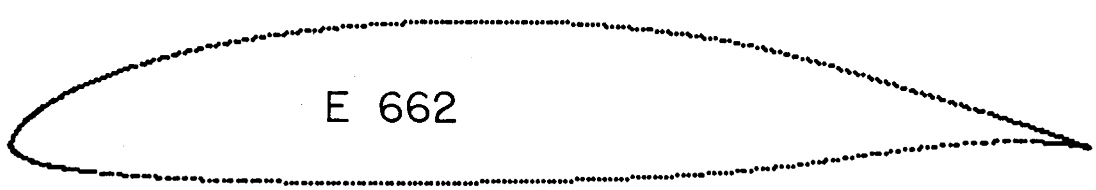
Also in this publication are articles concerning optimum tailplane design for sailplanes, the effects of disturbances on a wing (by Eppler), length and bursting of separation bubbles, and simple total energy sensors.

"Sailplanes with normally hinged flaps are a standard application of airfoils. The difficulties with this application come from two requirements. First, the flap-down case usually corresponds to a Reynolds number of $10^6$ or below. For this case, laminar separation bubbles can be dangerous. This danger is increased by the steep adverse pressure gradient immediately downstream of the suction peak at the flap hinge. Second, the negative-flap-deflection (up) case corresponds to $R > 3 \times 10^6$. For this case, transition can occur earlier than desired. For a zero pressure gradient at these Reynolds numbers, the boundary layer is not stable enough to remain laminar for 60% to 70% of the surface and, therefore, a certain favorable pressure gradient is necessary to keep the boundary layer laminar.

"Airfoil 662 was designed for this application... The pressure recovery on the upper surface for the undeflected-flap case must be less than would be possible for the case where no flap deflections were intended. A flap deflection in either direction increases the amount of adverse pressure gradient. Severe separation would occur in these cases if the pressure recovery for the undeflected case were already approaching the separation limit. The flap deflection can, however, be exploited in a favorable sense as well. For the flap-down case, a distinct transition ramp forms between the original pressure recovery and the suction peak caused by the flap. On the lower surface, an additional favorable pressure gradient occurs with the flap up which stabilizes the laminar boundary layer at the higher Reynolds numbers. Attention to all of these details together with the careful designing of the leading-edge suction region results in the good performance... Notice that, at low $C_l$ and low Rn, a lower-surface separation was again permitted."

EPPLER 662

| | | | |
|---|---|---|---|
| 100.000 | 0.000 | .003 | -.074 |
| 99.642 | .118 | .351 | -.733 |
| 98.640 | .483 | 1.336 | -1.289 |
| 97.117 | 1.056 | 2.879 | -1.875 |
| 95.113 | 1.745 | 4.966 | -2.210 |
| 92.609 | 2.516 | 7.571 | -2.567 |
| 89.626 | 3.395 | 10.668 | -2.858 |
| 86.231 | 4.390 | 14.221 | -3.088 |
| 82.500 | 5.493 | 18.189 | -3.264 |
| 78.528 | 6.682 | 22.522 | -3.392 |
| 74.435 | 7.890 | 27.165 | -3.474 |
| 70.276 | 8.968 | 32.061 | -3.512 |
| 65.983 | 9.824 | 37.148 | -3.506 |
| 61.519 | 10.489 | 42.363 | -3.456 |
| 56.922 | 10.988 | 47.642 | -3.357 |
| 52.232 | 11.331 | 52.919 | -3.206 |
| 47.501 | 11.525 | 58.130 | -2.993 |
| 42.776 | 11.570 | 63.214 | -2.702 |
| 38.108 | 11.470 | 68.116 | -2.302 |
| 33.541 | 11.225 | 72.841 | -1.742 |
| 29.121 | 10.841 | 77.449 | -1.061 |
| 24.891 | 10.324 | 81.940 | -.382 |
| 20.891 | 9.681 | 86.229 | .169 |
| 17.159 | 8.923 | 90.177 | .509 |
| 13.729 | 8.062 | 93.628 | .611 |
| 10.631 | 7.113 | 96.423 | .500 |
| 7.892 | 6.094 | 98.431 | .276 |
| 5.535 | 5.024 | 99.613 | .077 |
| 3.578 | 3.926 | 100.000 | -.000 |
| 2.037 | 2.828 | | |
| .921 | 1.761 | | |
| .239 | .770 | | |



## HQ35/12.29

Proceedings of the Conference on Low Reynolds Number Airfoil Aerodynamics
Sponsored by NASA Langley Research Center, Hampton VA, the U.S. Navy Office of Naval Resarch, and the University of Notre Dame, Department of Aerospace and Mechanical Engineering
June, 1985
Thomas J. Mueller, Ph.D., Editor; Department of Aerospace and Mechanical Engineering; University of Notre Dame; Notre Dame IN 46556.

Research on Laminar Separation Bubbles at Delft University of Technology in Relation to Low Reynolds Number Aerodynamics, by J.L. van Ingens and L.M.M. Boermans, Department of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands

Also included in this publication are articles concerning low Reynolds number airfoil design (one by Eppler, another by Selig), effects of aspect ratio on the hysteresis loop, the effect of trip wires on air flow, and several articles on laminar separation bubbles.

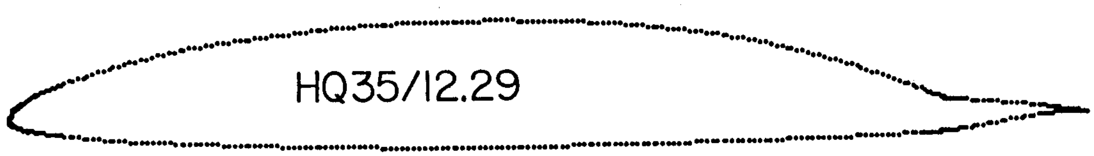
"Another airfoil for sailplane application, HQ35/12.29, designed by K.H. Horstmann and A. Quast of DFVLR Braunschweig (West-Germany)... This 12.29% c thick airfoil has a camber changing flap of 13.5% chord length. In actual practice this flap extends along the whole span of the sailplane wing. Very long laminar flow regions are present on both the upper and lower surface as shown in the measured pressure distributions. Due to the stability of the laminar boundary layer and the pressure rise on the rear of the airfoil, laminar separation bubbles are present again. ...drag decrease obtained with zig-zag tape, mentioned before, at 69% c on the upper surface and 83% c on the lower surface...

"The concave corner in the upper and/or lower surface contour at the flap hinge leads to local separation of the turbulent boundary layer. Systematically filling and rounding of this corner did not result in a drag reduction. More research is needed to exploit this phenomenon."

<u>HQ35/12.29</u>

| | |
|---|---|
| 100 | 0 |
| 97.5 | .23 |
| 95 | .69 |
| 90 | 1.04 |
| 86.5 | 1.27 |
| 86.5 | 1.27 |
| 85 | 1.85 |
| 80 | 3.7 |
| 75 | 5.32 |
| 70 | 6.47 |
| 65 | 7.52 |
| 60 | 8.09 |
| 55 | 8.55 |
| 50 | 8.79 |
| 45 | 8.9 |
| 40 | 8.79 |
| 35 | 8.67 |
| 30 | 8.32 |
| 25 | 7.75 |
| 20 | 7.17 |
| 15 | 6.36 |
| 10 | 5.09 |
| 5 | 3.58 |
| 2.5 | 2.54 |
| 1 | 1.5 |
| .5 | 1.16 |
| .25 | .92 |
| 0 | 0 |

| | |
|---|---|
| .25 | -.35 |
| .5 | -.46 |
| 1 | -.69 |
| 2.5 | -1.04 |
| 5 | -1.39 |
| 10 | -1.97 |
| 15 | -2.2 |
| 20 | -2.43 |
| 25 | -2.62 |
| 30 | -2.77 |
| 35 | -2.83 |
| 40 | -2.89 |
| 45 | -2.89 |
| 50 | -2.83 |
| 55 | -2.77 |
| 60 | -2.66 |
| 65 | -2.55 |
| 70 | -2.43 |
| 75 | -2.31 |
| 80 | -2.08 |
| 85 | -1.85 |
| 86.5 | -1.73 |
| - flap hinge line - | |
| 86.5 | -1.73 |
| 90 | -1.16 |
| 95 | -.23 |
| 97.5 | 0 |
| 100 | 0 |



## "Zig-Zag" Turbulator

A "zig-zag" turbulator for use on the DU 86-084/18, or for experimentation, is available from Glasfaser-Flugzeugbau, Hafner Weg, 7431 Grabenstetten, Germany. A length of 14 meters (nearly 46 ft.) costs 63,-DM (about US$42.00 at the current exchange rate).

A domestic source for zig-zag turbulators is Hobby Lobby International, Inc., 5614 Franklin Pike Circle, Brentwood TN 37027. The material from Hobby Lobby comes in two different styles and four different colors (white, black, red, or yellow). Each package contains 47" of 1/8" wide zig-zag strip, and 24" of 2" wide material which is zig-zag cut at one edge and straight on the other. The narrow "Z band" is as used on the DU 86-084/18 section, while the wider is described as being a combination turbulator and hinge gap cover. For $5.45 you can get both turbulators, as described above, in a single package.

Some reports indicate that a zig-zag turbulator is more efficient (better turbulation for less drag) than a "trip strip."

## THE ASM-LRN-007 SECTION

A few months back we described an airfoil specifically designed for F3B, the DU 86-084/18. This month we take a look at a section suitable for thermal duration events, the ASM-LRN-007. This section was described in some detail in a recent issue of the Journal of Aircraft[1].

As is now commonplace, the ASM-LRN-007 is a computer designed section. The computer program, by Mark Drela of MIT, is the same used by Michael Selig and John Donovan during the Princeton wind tunnel tests. Please note the ASM-LRN-007 has not been wind tunnel or flight tested. With a computed section $c_l/c_d$ of up to 166 and a maximum $c_l$ of 1.5, however, it appears to be a very high performance section worthy of some experimentation. The ASM-LRN-007 is for conventional tailed aircraft.

The ASM-LRN-007 is the result of a quest for an airfoil capable of high lift with low drag within the Reynolds number regime of 250,000 to 500,000, with minimum laminar separation. The condor and albatross both soar at the lower end of this range - the condor as a static soarer, the albatross as a dynamic soarer. They were thus of great interest to the investigators, and the ASM-LRN-007 has several characteristics which reflect this heritage: an undercut front lower surface and relatively sharp leading edge, an undercut trailing edge (aft loading), and a requirement for turbulation. The thickest portion of the airfoil extends from about 25% to nearly 50% chord, allowing for a substantial spar system. In fact, the ASM-LRN-007 is very similar to a bird-like airfoil described previously in RCSD[2]. The ASM-LRN-007 was designed for a 16% flap capable of both positive and negative deflection.

The undercut front lower surface adds additional positive lift and decreases the airfoil's pitching moment. This narrows the low-drag bucket, but the benefits derived are felt to outweigh this. Aft loading is compatible with full chord laminar flow on the lower surface during high $c_l$. Reducing the front lower surface undercut and/or reducing the aft-loading would result in a significantly lower $c_l/c_d$. The low-drag bucket, on the other hand, is expanded through the use of flaps. Laminar flow to 67% chord on the upper surface is possible. Laminar separation is prevented through use of a zig-zag turbulator strip. Unfortunately, the actual location of the turbulator is not given in the article. The implied location is at about 70% chord. Moving the turbulator on one wing at a time and comparing flight performance (looking for yaw and/or roll) could quickly lead to an optimum position.

The performance chart was derived from the published polars, the coordinates are from C.S. Vemuru, courtesy of Michael Selig.

An added note: Pfenninger and Vemuru suggest the zig-zag turbulator is more effective than a two-dimensional "trip strip" and can thus be made thinner, with an accompanied drag reduction of significant proportions. (Birds use a series of reversed "zig-zag" turbulators as their wing feathers form a series of rounded backward facing steps.) Even more effective, however, is turbulation by means of one or several rows of very small suction holes. Pfenninger and Verumu claim this method to have zero drag, and in some cases <u>negative</u> drag! This too might be worthy of some additional experimentation, as the air volume which needs to be moved is extremely small.

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[1]Pfenninger, W. and Vemuru, C.S., "Design of Low Reynolds Number Airfoils: Part I," <u>Journal of Aircraft</u>, Volume 27, March 1990, pp. 204-210.

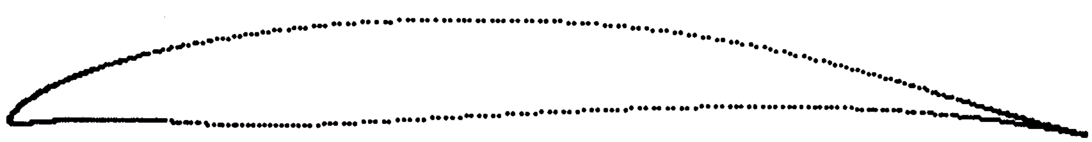
[2]Gray, J., "Interesting Airfoil Information," <u>RC Soaring Digest</u>, July 1988, pp. 4-5).

COMPUTED PERFORMANCE, ASM-LRN-007

| Flap Deflection | Reynolds Number | Angle of Attack | Lift Coefficient | $c_l/c_d$ |
|---|---|---|---|---|
| -10 | 250,000 | 5.4 | .85 | 87 |
| -10 | 500,000 | 5.4 | .85 | 125 |
| -5 | 250,000 | 4.5 | .96 | 103 |
| -5 | 500,000 | 6.8 | 1.20 | 142 |
| 0 | 250,000 | 6.0 | 1.37 | 117 |
| 0 | 500,000 | 5.2 | 1.30 | 160 |
| +5 | 250,000 | 5.5 | 1.50 | 120 |
| +5 | 500,000 | 4.2 | 1.42 | 166 |

## ASM-LRN-007

| | | | |
|---|---|---|---|
| 1.000000 | -0.006579 | 0.000492 | -0.001132 |
| 0.994687 | -0.005338 | 0.004292 | -0.002574 |
| 0.988839 | -0.003987 | 0.008768 | -0.002421 |
| 0.982359 | -0.002438 | 0.013597 | -0.001911 |
| 0.975104 | -0.000636 | 0.018847 | -0.001293 |
| 0.966870 | 0.001460 | 0.024602 | -0.000607 |
| 0.957377 | 0.003934 | 0.030971 | 0.000083 |
| 0.946221 | 0.006923 | 0.038092 | 0.000734 |
| 0.932783 | 0.010609 | 0.046143 | 0.001376 |
| 0.916105 | 0.015282 | 0.055373 | 0.001992 |
| 0.894667 | 0.021415 | 0.066137 | 0.002530 |
| 0.866143 | 0.029672 | 0.078956 | 0.002893 |
| 0.827779 | 0.040997 | 0.094608 | 0.003024 |
| 0.778224 | 0.054996 | 0.114295 | 0.002730 |
| 0.719972 | 0.069342 | 0.139812 | 0.001708 |
| 0.657036 | 0.081643 | 0.173498 | -0.000644 |
| 0.591956 | 0.090680 | 0.217161 | -0.003214 |
| 0.525878 | 0.096436 | 0.270294 | -0.001942 |
| 0.459409 | 0.099113 | 0.330209 | 0.001573 |
| 0.393043 | 0.098902 | 0.393431 | 0.005701 |
| 0.327604 | 0.095744 | 0.457841 | 0.009758 |
| 0.264873 | 0.089960 | 0.522511 | 0.013417 |
| 0.208407 | 0.081988 | 0.586986 | 0.016355 |
| 0.162190 | 0.073203 | 0.650839 | 0.018230 |
| 0.127258 | 0.064945 | 0.713009 | 0.018826 |
| 0.101455 | 0.057634 | 0.770989 | 0.018063 |
| 0.082011 | 0.051260 | 0.820959 | 0.016064 |
| 0.066869 | 0.045668 | 0.860395 | 0.013220 |
| 0.054708 | 0.040666 | 0.890146 | 0.010177 |
| 0.044686 | 0.036112 | 0.912677 | 0.007508 |
| 0.036255 | 0.031908 | 0.930215 | 0.005145 |
| 0.029056 | 0.027967 | 0.944316 | 0.003078 |
| 0.022843 | 0.024219 | 0.955985 | 0.001276 |
| 0.017441 | 0.020616 | 0.965876 | -0.000314 |
| 0.012756 | 0.017081 | 0.974423 | -0.001738 |
| 0.008715 | 0.013574 | 0.981920 | -0.003063 |
| 0.005297 | 0.010045 | 0.988584 | -0.004305 |
| 0.002573 | 0.006412 | 0.994570 | -0.005481 |
| 0.000512 | 0.002732 | 1.000000 | -0.006579 |



ASM-LRN-007

## AEROSPACE COMPOSITES' UNIDIRECTIONAL FIBERGLASS CLOTH and GEARS FOR JR'S MICRO SERVO

Swept wings require both resistance to bending along the span, and torsional rigidity. Without resorting to a balsa skin, the first requirement has been an elusive goal for us. During construction of Penumbra.4, however, we had the opportunity to work with a new and unique type of unidirectional fiberglass cloth, and it now appears our elusive goal has been attained.

Unidirectional cloth usually consists of two sets of fibers. The first set, about 90% of the total, runs the length of the fabric; the second set is woven at 90 degrees to the main fibers and serves to hold the material together. These unidirectional fabrics are usually woven from threads, each consisting of many individual glass fibers. The lightest unidirectional cloth we were able to find was 6oz./yd.$^2$ - too heavy for our application.

Enter a 4 oz./yd.$^2$ unidirectional S-glass fabric from Aerospace Composites and George Sparr. This fabric is beautiful! Rather than "ropes" of glass fiber, this Aerospace Composites cloth consists of ribbons of glass fibers. Each of these ribbons is about 3/32" wide and is the thickness of a single glass fiber. Spacing between the ribbons is about 1/32", held in place by very fine fibers of seemingly continuous length. These lightweight fibers, which may be of polyester, appear to have been sprayed on in a random way. There is no determinable pattern, but the coverage is very even and their strength is rather remarkable.

In our experience, all cutting was easily accomplished with ordinary plastic handled stainless steel scissors. Our application required cutting curves, so a cardstock template was made. No problems were experienced, regardless of cutting direction. Some minor curling was noticed, but this disappeared completely once we started applying epoxy. The epoxy, although on the thick side, flowed through the fabric quite easily. We used flexible plastic squeegees to spread it evenly. Those lightweight random fibers stayed in place throughout all of our scrapings, but we made sure we always moved the squeegees and blade with the grain so as not to apply too much stress to them.

Our layup consisted of two light coats of vinyl paint applied directly to the mylar, a layer of 3 oz./yd.$^2$ bidirectional cloth oriented on the bias (45 degrees), then the Aerospace Composites unidirectional cloth. This was then vacuum bagged to a pink foam core.

The over all result is fantastic! The 3 oz./yd.$^2$ bidirectional cloth provides an excellent exterior surface, particularly with the vinyl paint exposed, and imparts a large amount of torsional strength to the wing. The spanwise strength provided by the 4 oz./yd.$^2$ unidirectional cloth is far greater than what was achieved with the two and three layers of 3 oz./yd.$^2$ bidirectional cloth we previously used. Total weight remains the same. With an integral carbon fiber reinforced spar system, this wing is incredibly rigid.

The 4 oz./yd.$^2$ unidirectional S-glass comes in a width of 30 cm (just under 12"). It is available only from Aerospace Composites. Please mention RCSD and "On The 'Wing..." when ordering. Thanks!

* * *

Our nine JR micro servos are now humming along happily following the arrival of a dozen output shafts. The output shaft of the 305 became the weak link when JR incorporated metal gears in the train some years ago. Spending several dollars for the whole gear set is no longer necessary as you can now obtain the output shafts alone for under a dollar each! The JR 305 micro servo is a gem and needn't lie idle for lack of this critical part. Ask for Part #JRA65305E.

# A MULTIDISCIPLINARY APPROACH TO DESIGN

A recent issue of the Journal of Aircraft, published by the American Institute of Aeronautics and Astronautics, was devoted to optimization of aeronautical systems through multidisciplinary approaches.

The most interesting article for us was one directed toward actively controlled fiber composite wings[1]. Although the article itself was very heavily mathematics oriented, several charts and diagrams provided basic information of use to model builders. What follows is not a review or condensation of the article, but rather a description of a derived design methodology/philosophy which is suitable for both tailless and conventional RC sailplanes.

## CONSTRAINTS

Any design process begins with a determination of the constraints imposed on the eventual design. All of our models must conform to the majority of the FAI regulations for RC sailplanes. From the start, then, we know the wing loading must be over 4 oz/ft$^2$ and under 24 oz/ft$^2$. We also know the mass of our completed glider must be below 5 kg (176 oz). Other constraints include the minimum nose radius, a ban on telemetry, and a requirement that all model controls be actuated from the ground, but not all of these are adhered to by AMA regulations. (Thermal sniffers and electrostatic stabilizers can be used in AMA competition.) Additionally, our design may be constrained by certain AMA regulations regarding span, or local rules may define a maximum number or type of control surface.

## DESIGN APPROACH

The main thrust of all of the articles in the Journal of Aircraft is the entire design approach needs to be based on a multidisciplinary process in which each segment to be optimized affects all other segments. This implies that while we will of course endeavor to maximize overall sailplane performance, our method of achieving this goal will simultaneously encompass structural, aerodynamic, and control systems, while always remaining within those previously defined restraints. As we explain these systems in detail, through example, we will outline their relationships.

## STRUCTURE

Overall size, in our opinion, should be the designer's first consideration. As a pertinent example, we have recently been giving greater thought to winch power versus sailplane size. This came about because our two meter 'wing, the Blackbird, with 1250 $in^2$ of wing area, can not really take advantage of the power available from our winch. Even very strong zoom launches do not tax its capabilities. At the other extreme, our XC version of the Blackbird (2300 $in^2$) overloads the winch to an extreme degree. What we need is a 'wing with about 1700 to 1800 $in^2$ of area. We feel this would allow most efficient use of winch power, while at the same time improve performance compared to the two meter version. If you are designing for contest flying prescribed by AMA regulations, such manipulations of wing area may not be possible to a large extent due to wing span limitations and the desire for optimum aspect ratio. For FAI events, however, such size optimization is both possible and desirable.

Of related interest is flying weight (mass). This is because mass and size are usually positively related and because required lift is directly related to mass. Mass also has an effect on other performance characteristics, such as speed.

Sailplane structure also includes overall planform (tailed vs. tailless, tapered vs. constant chord, sweepback, etc.) The stresses imposed on the wing panels will vary depending on whether or not there is a fuselage, and other distribution-of-mass factors, so spars must be sized for strength and located where strength can be put to best use. It should also be kept in mind the structure may also be influential in drag reduction, as we'll describe in more detail in the next section.

## AERODYNAMICS

The portion of the design process devoted to aerodynamics was really introduced in this article when we spoke of the lift necessary to support the mass of the sailplane. Airfoil choice is dependent upon camber, which dictates the amount of lift generated. Lift can be augmented, always with some penalty, through use of various control surface movements. Flaps, as an example, change the camber line and thus influence lift, but with the penalty of higher drag. Local aerodynamics are changed through control surface deflection.

Also influencing the sailplane's aerodynamics is wing shape. Lowest drag is achieved with some small amount of sweepback of the quarter chord line, for instance, and the lift distribution can be tailored to specific requirements through transitioning of airfoils and careful attention to taper.

Consideration must also be given to overall drag. The shape of the lifting surfaces is certainly important, but the wing-fuselage junction, empennage configuration, hinge design, and other factors must also receive careful attention. Of recent interest to modelers is the measurably lower drag of foam core wings when compared with that of open framework structures. The smooth ridge free skin of the foam core wing creates smaller and less numerous vortices.

## CONTROL

Velocity, glide angle, and other important variables are easily examined as the sailplane is traveling in a straight line. But our goal when installing RC gear is to have an aircraft capable of turning and having its altitude, attitude, and speed varied according to our input. We wish to have control of the sailplane during its flight, and hopefully with as little degradation of performance as possible. So we install a rudder, elevator, ailerons, flaps, spoilers, air brakes... anything which we feel will allow us some added degree of control and which we hope will allow us to go up more easily, and come down safely and effectively when desired.

Control surface deflection will always have some aerodynamic effect, and this effect will always be transferred to the aircraft's structure. Many of us forget this relationship during the design process. We must not only consider the loads imposed upon the servos and control systems, but also the stresses which are imposed upon the aircraft as a whole. Steeply banked turns place tremendous loads on the conventional tailed sailplane's wing center section. While servos may easily handle the aerodynamic load generated by the deflected control surfaces, the spar and spar-fuselage connection must also remain intact.

## INTEGRATION OF THE THREE SYSTEMS

It should be evident from the above that structure, aerodynamics, and control are interwoven to the point of being inseparable, and a change in one aspect of the design process affects all three realms. While our primary design goal is always the maximizing of sailplane performance, it should also be obvious an immense number of design objectives must be met in the process. Improved glide angle, quicker turns, increased roll rate, greater velocity, or better thermal performance may be classed as design goals. But such things as control of wing flex and twist, freedom from flutter within the prescribed speed range, dynamic stability, effective control, maximum lift with minimum increase in drag, and retention of spar integrity under expected g loads are also inherent considerations within the design process. It is the successful integration of the three disciplines - structure, aerodynamics, and control - which produces the optimum sailplane for a particular task.

By developing a more complete understanding of these three disciplines, their interrelationships and the design process, better sailplanes can be produced.

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## DRAW TAILLESS

```
1     REM  **** DRAW TAILLESS ****
10    CALL  - 936
20    PRINT "DRAW TAILLESS will provide a line"
30    PRINT "sketch using input parameters."
40    PRINT : PRINT "What is the sweep ratio? ";: INPUT SR
50    PRINT : PRINT "What is the root chord? ";: INPUT RC
60    PRINT : PRINT "What is the tip chord? ";: INPUT TC
61    PRINT : PRINT "Do you want the vertical fin area on thewing
      tips or on the center line?        ENTER 'W' for Winglets
      'S' for Single fin": INPUT A$
63    IF A$ <  > "W" AND A$ <  > "S" THEN  VTAB (9): GOTO 61
70    REM   ***** RADIANS
80    R = 57.2957795
90    REM  ***** SIN
100   S6 =  SIN (60 / R)
110   S2 =  SIN (240 / R)
120   REM  ***** COS
130   C6 =  COS (60 / R)
140   C2 =  COS (240 / R)
150   H = 88
160   V = 50
170   PRINT : PRINT "Span (150 = Max.)? ";: INPUT SP
171   IF SP > 150 THEN  VTAB (15): GOTO 170
180   HS = SP / 2
190   CH = (RC + TC) / 2
200   SW = SR * CH
210   WS = SW + TC - RC
220   A = (SP * (SW + TC)) - (HS * SW) - (HS * WS)
230   IS =  SQR (((SW + TC / 2 - RC / 2) ^ 2) + (HS ^ 2)) * 2
240   AR = IS / CH
250   HGR : HCOLOR= 3
260   REM H=88, V=50
270   HPLOT H,V
280   REM ***** A
290   HPLOT  TO H + S6 * 100,V + C2 * 100
300   HPLOT H,V
310   REM ***** B
320   HPLOT  TO H + S6 * 100,V + C6 * 100
330   HPLOT H,V
340   REM ***** C
350   HPLOT  TO H + S2 * 100,V + C6 * 100
360   HPLOT H,V
370   REM ***** D
380   HPLOT  TO H + S2 * 100,V + C2 * 100
390   HPLOT H,V
391   REM  CG
392   HC = H + S6 * ((SW + .001) / 2 + CH / 4)
393   VC = V + C6 * ((SW + .001) / 2 + CH / 4)
394   HPLOT HC,VC + 10 TO HC,VC - 10
400   REM ***** RT L.E.
401   HPLOT H,V
410   HO = H + S6 * HS + S6 * SW
```

```
420  VE = V + C2 * HS + C6 * SW
421  HT = HO:VT = VE
430  HPLOT  TO HO,VE
440  REM  ***** RT TIP
450  HO = HO + S6 * TC
460  VE = VE + C6 * TC
470  HPLOT  TO HO,VE
471  REM  RT WINGLET
472  IF A$ <  > "W" THEN  GOTO 480
473  H0 = HT + S6 * .3 * TC:V0 = VT + C6 * .3 * TC
474  H1 = H0:V1 = VE - .2 * HS
475  H2 = H1 + S6 * .35 * TC:V2 = V1 + C6 * .35 * TC
476  HPLOT H0,V0 TO H1,V1 TO H2,V2 TO HO,VE
480  REM ***** RT T.E.
490  HO = H + S6 * RC
500  VE = V + C6 * RC
510  HPLOT  TO HO,VE
520  REM ***** LT L.E.
530  HPLOT H,V
540  HO = H + S2 * HS + S6 * SW
550  VE = V + C6 * HS + C6 * SW
560  HPLOT  TO HO,VE
561  HT = HO:VT = VE
570  REM ***** LT TIP
580  HO = HO + S6 * TC
590  VE = VE + C6 * TC
600  HPLOT  TO HO,VE
601  REM  LT WINGLET
602  IF A$ <  > "W" THEN  GOTO 610
603  H0 = HT + S6 * .3 * TC:V0 = VT + C6 * .3 * TC
604  H1 = H0:V1 = VE - .2 * HS
605  H2 = H1 + S6 * .35 * TC:V2 = V1 + C6 * .35 * TC
606  HPLOT H0,V0 TO H1,V1 TO H2,V2 TO HO,VE
610  REM ***** LT T.E.
620  HO = H + S6 * RC
630  VE = V + C6 * RC
640  HPLOT  TO HO,VE
641  REM  SINGLE TAIL
642  IF A$ <  > "S" GOTO 650
643  TA = A / 10:S =  SQR (TA)
644  H0 = HO + S6 * S:V0 = VE + C6 * S
645  H1 = H0:V1 = V0 - S
646  H2 = H1 + S2 * .4 * S:V2 = V1 + C2 * .4 * S
647  HPLOT HO,VE TO H0,V0 TO H1,V1 TO H2,V2 TO HO,VE
650  REM PRINT DATA
660  VTAB 24: PRINT "Area = "; INT (A);"       Aspect Ratio = ";
     INT (AR * 100) / 100
665  PRINT "Root Chord = ";RC;"   Tip Chord = ";TC
668  PRINT "Sweep Ratio = ";SR
670  PRINT "Another design? ";: GET A$: PRINT A$: IF A$ = "N"
     THEN  TEXT : HOME : END
671  IF A$ = "Y" THEN  TEXT : HOME : GOTO 40
672  VTAB 23: GOTO 670
```

SUPPLEMENT

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