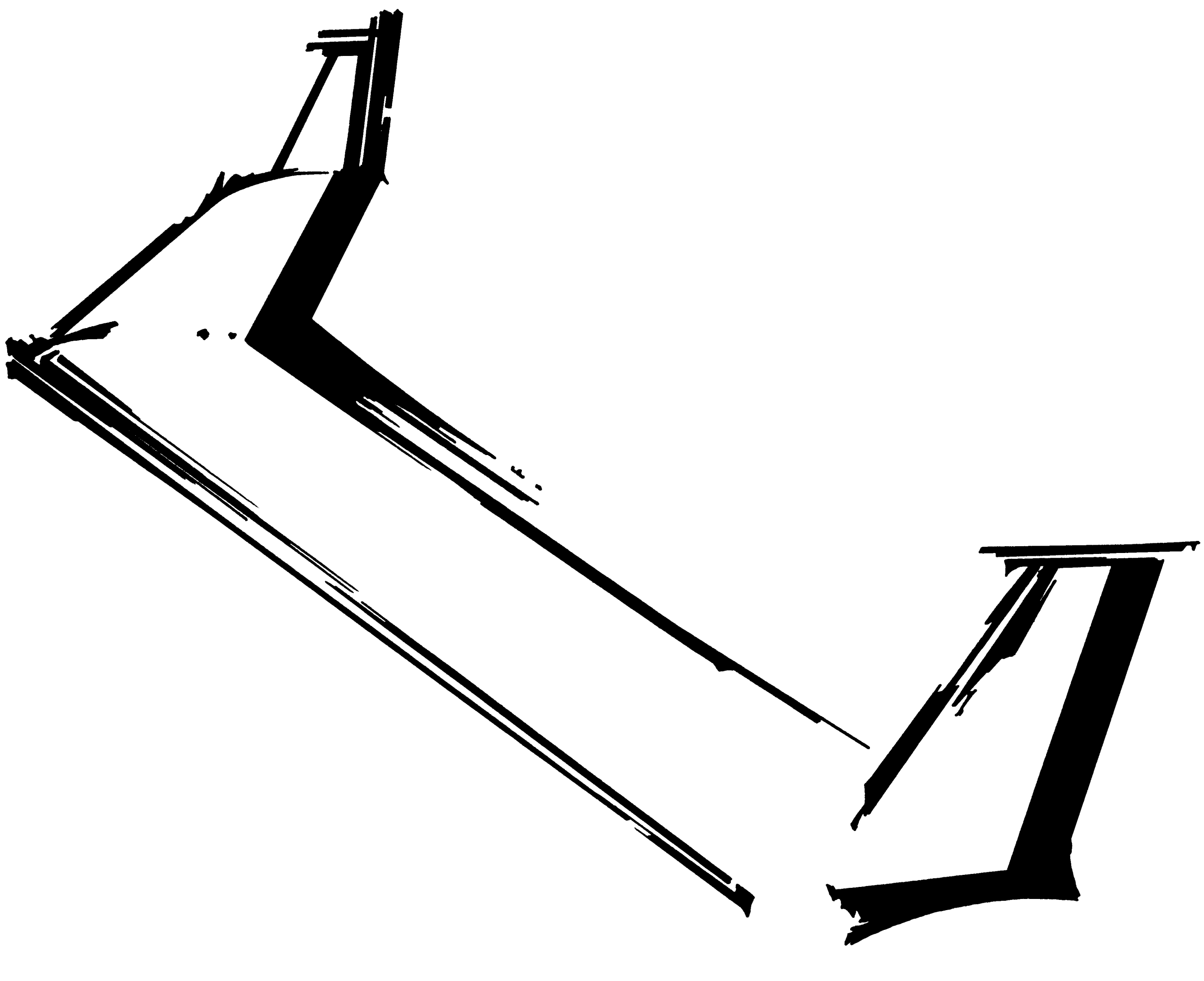
ON THE 'WING...

the book, Volume 2



BILL & BUNNY KUHLMAN

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This book was composed entirely on a Macintosh Centris 650 44/250 CD-ROM and a Macintosh PowerBook 180 14/130 using the MacHandwriter system and FrameMaker 3.0. The text is set in Bookman and Symbol; Helvetica is used for titles and within figures and tables. A SyQuest EZ135 was used for all file storage. Scanned images were produced on a UMAX OA-1 using Ofoto 1.2, and UMAX Astra 1200S using VistaScan v 2.3.6. Some photos were taken using an Apple QuickTake 100 digital camera. Galley proofs and masters were printed on a Hewlett-Packard LaserJet 4M.

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This book is lovingly dedicated
to the memory of
William H. Kuhlman Jr.
(1921 - 1994)

PREFACE

It has been nine years since we first approached Jim Gray, then editor and publisher of *RC Soaring Digest*, about a monthly column devoted to tailless RC soarers. Jim not only accepted those first six columns *en masse*, he also supported, and in fact continues to support, our writing and publishing endeavors.

“On the ’Wing… the book, Volume 2” is a compilation of our monthly *RCSD* columns. This volume continues where the first, now in its second printing, left off, January 1993. The articles are once again organized in chronological order by date of publication.

As in the previous volume, articles have been revised only to correct typographical errors, update resources, or to make the text noticeably more readable. The original articles included here are in complete form, and supplemental information has been added where appropriate.

There are a number of people to whom we owe a great deal, and not only for this book. Jerry and Judy Slates, editors and publishers of *RC Soaring Digest*, continue to support us and promote both B^{2}Streamlines and “On the ’Wing…” Readers of our monthly column have sent in questions, lists of suggested topics, pictures and commentary, and a kit for review. As a result, we are never at a loss for either subject matter or materials.

“On the ’Wing… the book, Volume 2” is our third publication to be composed entirely on computer. As we write this, we are using the same computer with which we design models, plot airfoil templates, and send and receive electronic messages through the internet. This is an astounding change in computer capability since publication of “On the ’Wing… the book,” and we look forward expectantly to many more advances in the future. The same is true for tailless planforms. Rapid advances are being made in the critical areas of structure, stability, control, and performance, people’s perceptions of tailless aircraft are changing in a positive direction, and interest in “flying wings” is at an all time high and rapidly growing.

What an exciting time to live!

BILL & BUNNY KUHLMAN

Olalla
October 1997

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Larry Renger's "Foamme Fatale"

Build and fly a slope 'ship in one day, including travel time!

Now that we have your attention, we will tell you "Foamme Fatale" is a fun to fly tailless creation from the fertile mind of Larry Renger. Constructed of foam board with hot melt glue and tape, this little soarer builds rapidly and can take a lot of abuse.

You can also build this 30" span cutie from cardboard, but as Larry says, "Cardboarde Fatale" doesn't quite do it.

Foamme Fatale" rolls easily, but due to a low terminal velocity will not loop. Still, one most likely could not find an RC 'ship with a higher fun to cost ratio. Build one (or several) tonight!

Instructions

1. Lay everything out to minimize waste. You can get it all on 1½ sheets of foam core.

2. Cut everything out with a straight edge and a new #11 X-Acto blade. Hint: Hold the blade at a 45° angle while cutting the elevon hinge line, then switch the elevators side for side.

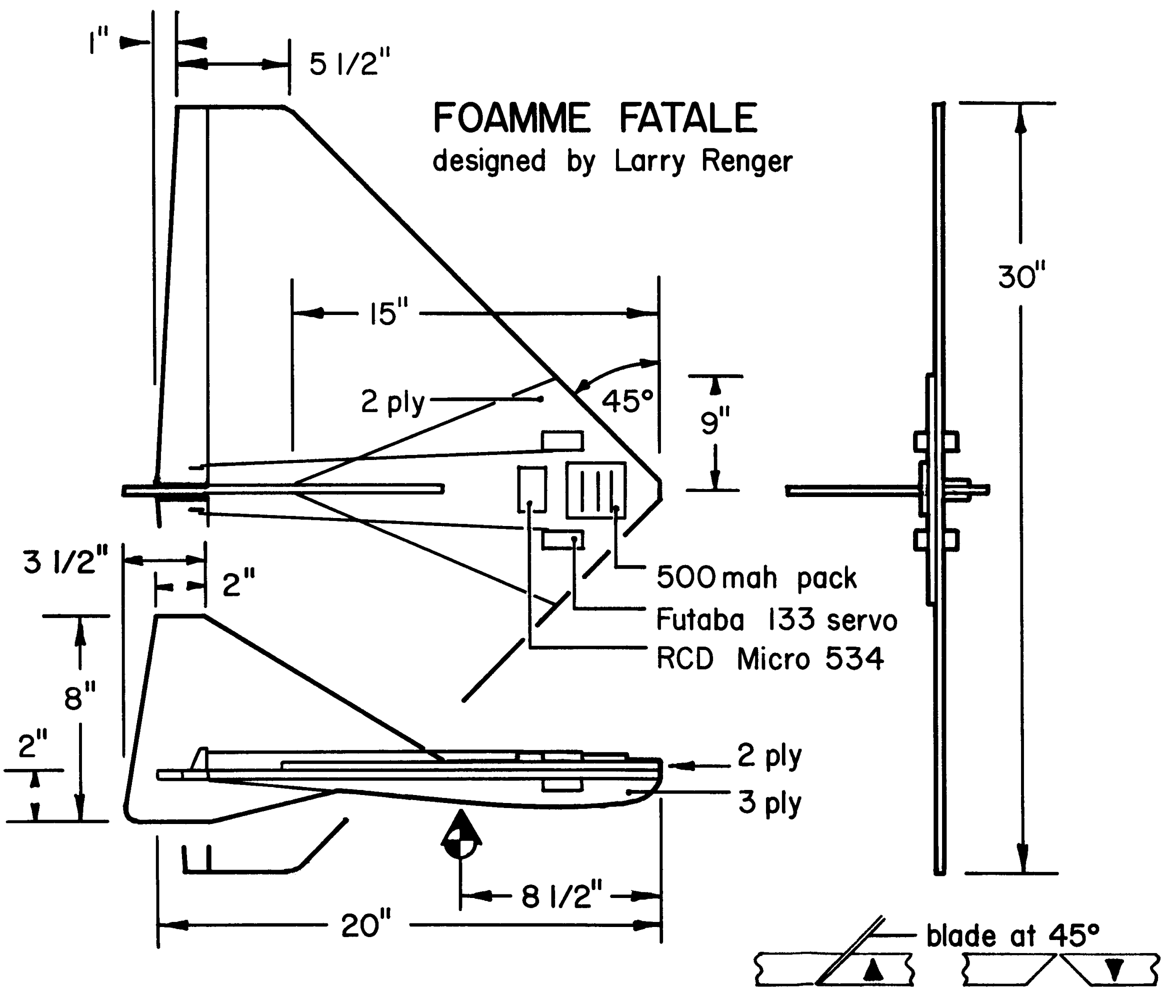
3. The entire model is glued together with hot melt glue. Use clear tape top and bottom for hinges.

4. Position the RC gear to get the proper CG, then inlet into the foam. Tape in place as needed.

5. Reinforce the leading edge of the wing and the lower fuselage with 'glass package strapping tape.

6. Arrange linkages for 3/32" up, then set controls to get about 3/8" each way on aileron and 1/4" on elevator.

7. Go throw it off a cliff!


1"
5 1/2"
FOAMME FATALE
designed by Larry Renger
30"
15"
2 ply
45°
9"
3 1/2"
2"
500 mah pack
Futaba 133 servo
RCD Micro 534
8"
2"
2 ply
3 ply
8 1/2"
20"
blade at 45°

Wing Blades
a construction project

Alan Halleck, during our recent visit to his home in Beaverton Oregon, demonstrated a rapid method of constructing receptacles for wing blades. We documented the construction of a generic receptacle, and with further assistance from Alan are able to present in step by step fashion the entire process for *RCSD* readers.

Steel wing blades provide far greater vertical strength than round wing rods of the same weight, and so have a distinct advantage over them. But a common problem facing builders is the construction of blade receptacles. Alan builds very strong receptacles from plywood, an easily worked material, following the procedure described here.

Begin construction by sketching the required joiner. See Figure 1. Do this by drawing a front view of your wing at the location of the joiner. The example we present involves a blade of 3/8" height and 1/16" thickness in a wing which is 3/4" thick. The blade joins the flat wing center panel and the removable wing tip. The dihedral angle is four degrees, and the joiner is six inches long. Two thicknesses of plywood will be used during construction. One piece (1/8" in thickness, or double the wing blade thickness) is used for the main portion of the assembly, while another (1/16" in thickness, or the

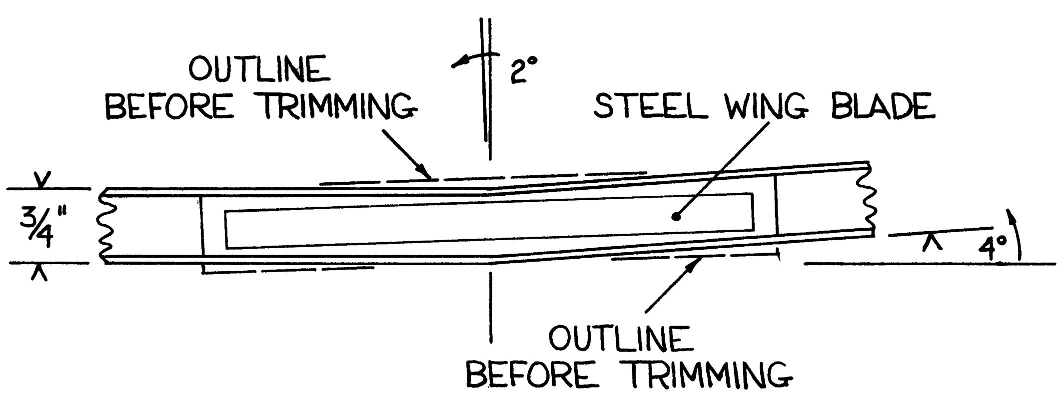


FIGURE 1

wing blade thickness) is used for the remainder. From the drawing we find the width of our plywood joiner before trimming must be at least 7/8" when the blade is centered within the structure. This width allows for some trimming of material upon completion of the basic structure, but minimizes waste. The receptacle length should be slightly longer than the steel blade to allow for end caps.

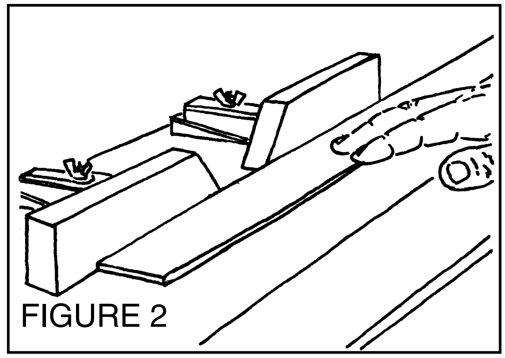


FIGURE 2

Actual construction starts with setting up the router table. See Figure 2. Use a square blade with a diameter equal to the height of the steel wing blade. (We used a 3/8" router blade to match the height of our wing blade.) Set the router fence so the plywood will be grooved at the correct distance from the edge.

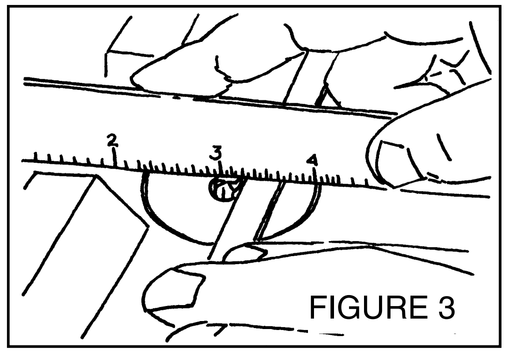


FIGURE 3

Now raise the router blade to the height of the wing blade width (in the example, 1/16"), plus just a fraction more. Use a straight edge when making the final adjustments. See Figure 3.This little bit of extra clearance prevents the wing blade from binding when inserted into the receptacle.

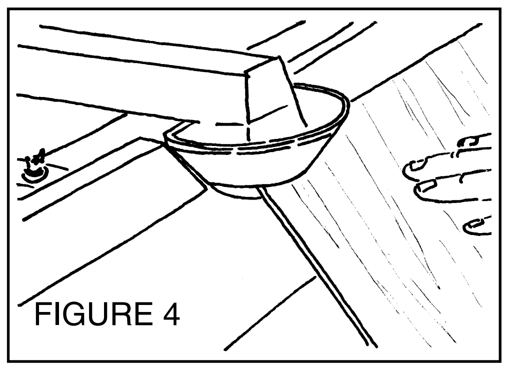


FIGURE 4

The 1/8" plywood, pre-cut at a 45° angle to the grain, is then put up against the router fence and a groove is cut into the underside of the piece. See Figure 4. In our example, the joiner blade is 1/16" thick, leaving 1/16" of the plywood to act as one joiner face.

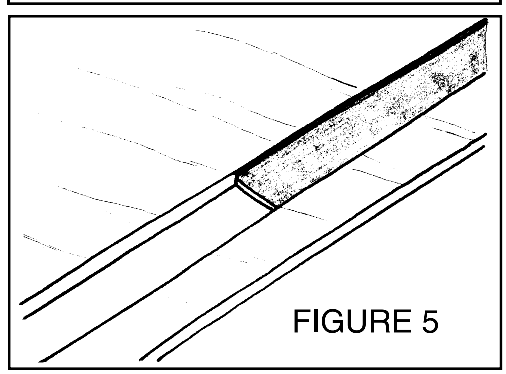


FIGURE 5

When completed, the steel joiner blade should be placed in the groove. See Figure 5. Check the depth of the groove — it should be just noticeably deeper than the wing blade itself. Remove the steel blade. Reroute the groove a little deeper if required, otherwise go to the next step.

Now measure across the 1/8" plywood to the predetermined width of the untrimmed joiner assembly See Figure 6.

A band saw or table saw is then used to cut the routed strip free. See Figure 7.

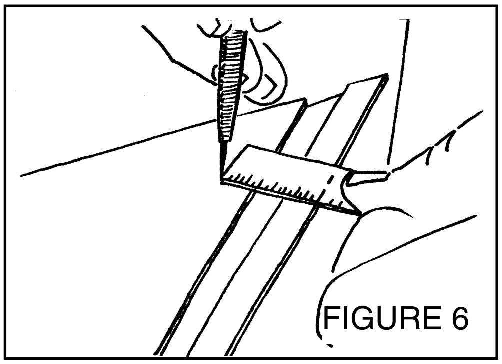


FIGURE 6

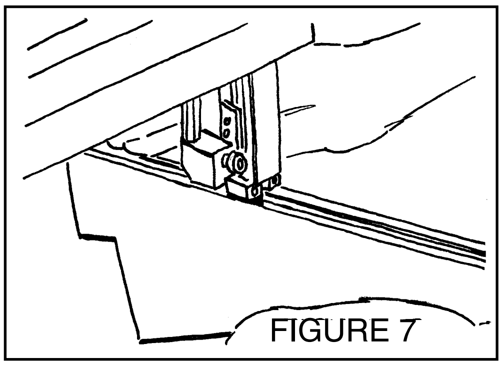


FIGURE 7

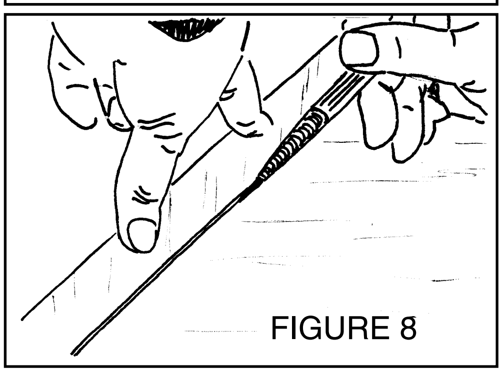


FIGURE 8

Place the completed piece on the 1/16" plywood. See Figure 8. Align the free edges and mark the 1/16" plywood using the 1/8" plywood as a straightedge. Remember, the strongest structure is obtained by orienting the grain of this face piece perpendicular to that of the routed piece.

Cut this marked strip free using a band saw or table saw. See Figure 9.

Spread out a piece of waxed paper or similar material to protect your work surface. Alan used a piece of Crown Freezer Paper ™. This material consists of a plastic film with a paper backing. Alan placed the plastic side up. Apply a thin coat of grease or some other releasing mechanism to the joiner blade and place it in the routed groove. Make sure one end protrudes from the eventual structure sufficiently for pliers to get a good grip on the end. Brush five minute epoxy on either side of the routed groove, see Figure 10, then place the 1/16" plywood strip on it. That's right, the wing blade should be inside the assembly during the curing process!

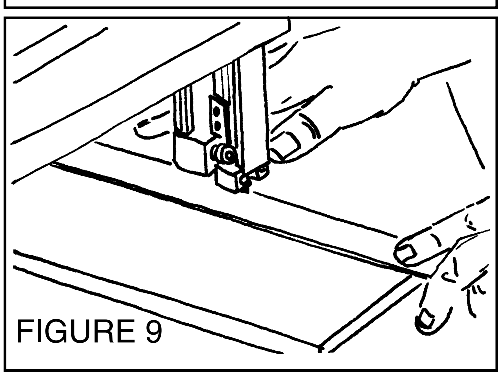


FIGURE 9

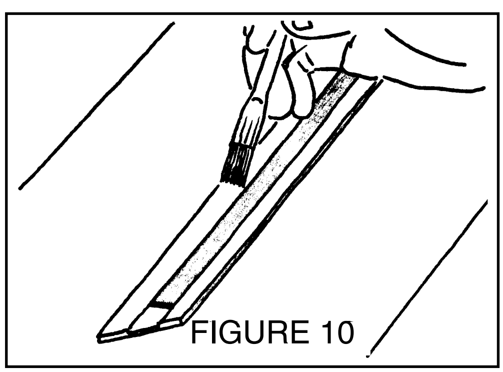


FIGURE 10

Align the assembly carefully and weight it for a good bond. Refer to the cutaway sketch, Figure 11, and the end view, Figure 12. When the epoxy is cured, grasp the free end of the steel wing blade with pliers and pull it out of the plywood assembly.

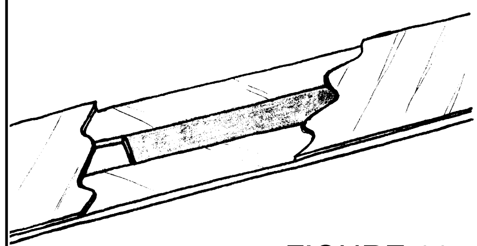


FIGURE 11

A tool, made from a piece of the steel blade material, can be used to scrape out any epoxy which interferes with the blade's insertion into the receptacle. See Figure 13.

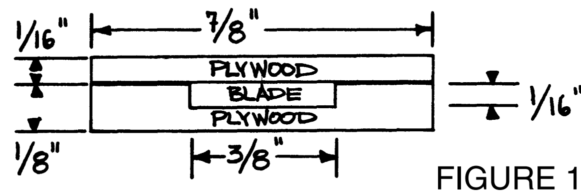


FIGURE 12

Trim the finished assembly to the size and shape required, referring to your original sketches. See Figure 14. Don't forget to epoxy small pieces of plywood into the open ends of the enclosed channel. This will prevent the steel wing blade from penetrating the wing's foam core or the spar webbing.

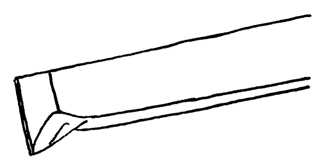


FIGURE 13

Wrap the entire assembly with two layers of Kevlar™ or Dacron™ thread. These wrappings should be closer together at the ends and middle of the joiner, where the plywood is thinnest and the blade might poke through. Add a filler to smooth.

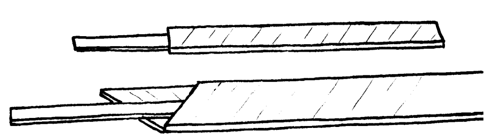


FIGURE 14

Slightly rounding the end of the steel blade will prevent the blade from scraping the inside of the plywood assembly and eventually loosening the desired snug fit.

The last step is cutting the receptacle into the two pieces required. This should be done along the angle of the wing's end caps at

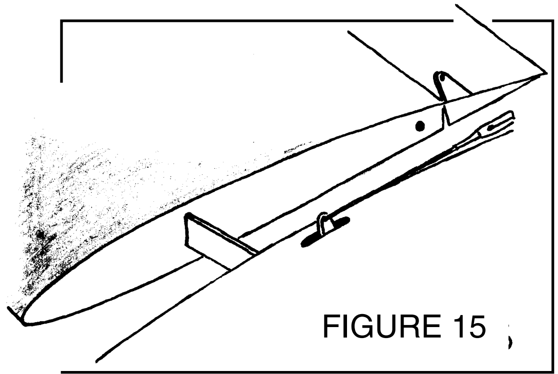


FIGURE 15

the separation point. Needless to say, the steel wing blade should not be inside the receptacle for this procedure.

Assembly of the completed wing at the flying field consists of sliding the wing halves together with the steel blade inserted in one half. See Figure 15. A small music wire pin near the trailing edge assure alignment, and a strip of tape seals the gap and serves to hold the wing halves together under normal flight loads.

When installed, a steel wing blade provide a large amount of vertical strength. On the other hand, the blade is weak in the fore and aft directions. This is of benefit, for when the wing swings forward, as during a hard landing, the blade bends and slides out of the receptacle, rather than the joiner assembly splitting open and destroying the integrity of the spar system.

Our sincere thanks to Alan for sharing this construction process with us, and particularly for his “slow motion” demonstration which gave us the time to get all of the essentials photographed and written down. Readers of *RCSD* should be able to put this information to good use.

Alan’s source of spring steel wing blades is: Pacific Machinery & Tool Steel Co., 3445 NW Luzon St., Portland OR 97210-1694; (503) 226-7656. The material used is blue tempered steel. This is available in thickness of 1/32", and 1/16", in widths of 1/4", 3/8", and 1/2". The cost of Alan’s eight foot length of 3/8" x 1/16" was $17.00. If you cannot find a local source, we recommend you call or write the above mentioned supplier for an up to date price and availability list.

Less is more.

— Mies Van Der Rohe

Proposed LSF Tailless Program

A rather exciting letter from Bob Champine showed up in our post office box in late December. Bob, to fill in some background, has been involved in aeromodeling for decades. Recently he contributed airfoils for use in the Princeton wind tunnel tests conducted by Michael Selig, John Donovan and David Fraser. Bob is the only person to have completed the League of Silent Flight program <u>twice</u>.

Bob's letter focused on a LSF (League of Silent Flight) program proposal which provides tasks and achievement levels for pilots of tailless RC sailplanes. This proposal is still in its formative stages, and so feedback is requested. The proposal in its final form is to be presented to the LSF for acceptance as a program separate from the one already in existence.

We would like to draw your attention to a couple of major points:

First, there are no contest points or contest requirements in this program. The main idea is to foster interest in tailless planforms as viable RC soaring machines and attract "grass roots" sport flyers in a task environment rather than in a competitive one. The idea is to accomplish goals rather than "to win." The tasks would, for the first time, make it possible for independent souls in remote areas to document their skills without having to find a tailless sailplane contest where none is ever likely to occur. The tasks of the program are themselves formidable and will reasonably challenge the abilities of anyone who attempts them.

Second, <u>all</u> tasks noted in any horizontal row must be completed before the designated level award is given. This is in contrast to the LSF program now in place, where there are some task choices available. Additionally, in this tailless program, a more difficult task in another row may be recorded before a lesser one, but the lesser task must be completed on a separate flight.

<u>LSF PROPOSED TASKS FOR FLYING WING ENTHUSIASTS</u>

- Tasks are to be performed with flying wings, that is models having no horizontal surfaces other than the wings itself.

- Witnesses must be 15 years of age, unrelated to the flyer, and a member of a national aero club (i.e., in the United States, the AMA, LSF, or SFA).

- Task accomplishments will be recorded on a task form by the flyer and the witness(es). A copy of this form will be filed with the LSF when each succeeding level is completed. However, any task at any level may be logged before the flyer completes lower levels of the Task Chart.

- No two tasks in vertical column under different colors on the Task Chart may be accomplished on the same day. However, other tasks in horizontal rows on the Task Chart may be completed and accomplished within a single flight. For example, a thermal duration, X-C, and landing task could be accomplished on the same flight for the Red or White level.

LEVEL	THERMAL DURATION	SLOPE	LANDINGS	X-C	ALTITUDE GAIN
RED	5 mins. 2x flat land	30 mins. mountains	within 3m 5x	1 km G&R flat land	N/A
WHITE	15 mins. 2x flat land	1 hour mountains	within 1.5m 10x	2 km G&R flat land	N/A
BLUE	30 mins. 2x flat land	2 hours mountains		3 km G&R flat land	700' 2x
SILVER	1 hour 2x flat land	4 hours mountains		4 km G&R flat land	1000' 2x
GOLD	2 hours 2x flat land	8 hours mountains		5 km G&R flat land	1500' 2x

2x = task to be accomplished twice
5x = task to be accomplished five times
10x = task to be accomplished ten times
G&R = Goal and Return: Course of required length is to be determined before flight. Takeoff may be at any point along the course, but <u>landing will be within 600 meters of takeoff point and will not shorten the course.</u>

Reminiscence

A small glider, tossed out over the hillside, just misses the top of the chain link fence, and its yellow wings rock in the turbulence created by the greenhouses below.The small orange rudder flicks momentarily to the right, and there is a barely audible hollow click as it dies so. Another click is heard as the rudder snaps back to its original position. Climbing a few feet, the little ship begins to drift back and forth over the crest of the hill, slightly canted into the sea breeze.

A sharp turn to the right becomes a spiral, and when the rudder is returned to neutral the glider's excess speed bleeds off in the form of a loop. A turn to the left at the exit point gets the 'ship back on track across the hill.

Several passes later it lands rather awkwardly behind the pilot. He turns off the transmitter and walks to his creation, now with its wing askew. The receiver is turned off, and the colorful little bird is brought back to the launching point.

Now the young flyer picks up a hand drill, a wire hook clamped in its jaws. The hook goes through a small metal ring in the tail of the glider, and a gentle pull on the drill succeeds in drawing out the loop of rubber. The drill rapidly twists the rubber until a row of knots is formed along the entire length of the loop. The metal piece is replaced, the receiver and transmitter are turned on, and the small glider is tossed out over the hillside once again. By the end of the day, when the breeze stops, the Nomad will have put in another 25 to 30 flights.

I was that young pilot, lucky enough to live on the crest of a hill overlooking the Pacific Ocean, with steady 15 m.p.h. winds coming up the slope nearly every day. Although the Nomad no longer exists, all of the primitive radio gear is still around and capable of reliable performance.

The vacuum tube transmitter, a CG Venus, uses two large 67½ volt batteries and a single 1½ volt D cell. Its front panel has an on/off switch mounted on the left and a red push button on the right.

The receiver is a Citizenship LT-3, one of the first of the transistorized units, tunable over nearly the entire 27 MHz spectrum. Powered by two 1½ volt batteries, it can drive either a solenoid or an electric motor.

In the Nomad, a solenoid was used to alternately release and stop a rotating shaft powered by a wound rubber loop. This escapement mechanism was connected to the rudder, driving it to extreme left and right positions and returning it to neutral when no signal was received.

When the pilot pushed the red button on the transmitter, a tone signal was sent to the receiver. The receiver then sent a three volt current to the escapement, releasing the shaft to rotate 1/4 turn and moving the rudder to the right. When the transmitter button was released, the current to the solenoid was stopped, and the shaft rotated another 1/4 turn, bringing the rudder back to neutral. The next time the transmitter was keyed, the rudder moved in the opposite direction. In flight, the diameter of a turn was controlled by the duration of rudder deflection and the time interval between commands.

While some fliers of the time rigged up additional mechanical systems capable of giving elevator control. Being able to reliably steer left and right was for me a wonder in itself! One of my biggest advancements was the purchase of an escapement which always gave right rudder at the first command.

Flight times with this type of system were always dependent upon the number of turns placed on the rubber loop and the ability of the pilot to fly with a minimum of control input. Still, this basic system served me well for nearly twenty years, giving reliable control of several sailplanes and powered aircraft, a few electric cars, and even a tug boat.

In the early '80s I bought a JR Century VII system. Proportional control of multiple surfaces and availability of mixing functions put this system light years ahead of the Nomad's equipment,

Newer systems, like JR's X-347, are even more advanced, offering multiple control presets, enhanced mixing capabilities, and other features. This setup allows one to build three control surfaces into each wing, and rudders into the fins, with independent control of each surface. The transmitter can then be programmed to move each surface so predetermined lift distributions are maintained throughout all flight regimes, extracting maximum performance from a swept wing tailless design.

Adequate means of control of high performance tailless RC aircraft has thus been possible only within the last decade or so, a fact not often appreciated. Now, with advanced airfoils, composite structures, and computerized radio systems, tailless sailplane performance is on the threshold of surpassing that of conventional designs.

A lot has been written about how this hobby should provide enjoyment for its participants — a notion with which we most heartily agree. What an aeromodeler builds and flies is thus an indicator of what provides the most enjoyment for him.

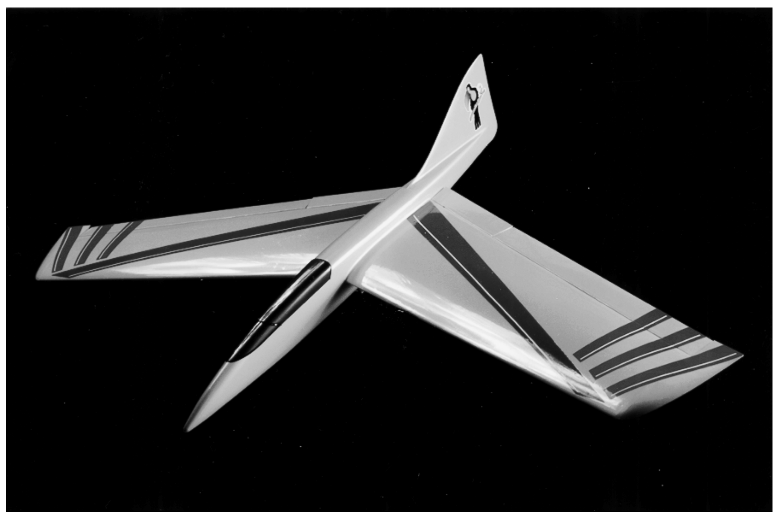
I remember with great fondness the many hours of pleasure the Nomad gave me, and I often consider spending a few days at the building board constructing another. But the challenge of utilizing current technologies in building and flying what is still considered an unorthodox planform has so far always won out. Being torn between these two extremes for over ten years has, however, been an extremely interesting experience and has provided much opportunity for introspection.

Blackbird 2M in flight. Photo by Andrew Still.

Larry Renger's "Toucan"

Larry Renger, of "Foamme Fatale" fame (*RCSD* 01/93), is currently involved in three projects of interest to readers of this column.

Another of Larry's designs, "Toucan," will appear as a construction article in the August issue of *Model Airplane News*. "Toucan" is a 42" span tailless design which features forward sweep. At home on the slope, "Toucan" has a rapid roll rate, turns quickly, and looks spectacular in the air. With a symmetrical airfoil and no twist, it is just as happy inverted as upright.



"Toucan" lends itself well to a variety of construction materials and methods. The plans show the wings constructed of one pound density foam cores covered with epoxy soaked brown wrapping paper. Alternative coverings include fiberglass over paper, fiberglass and epoxy alone, and 1/64" plywood. The wing is thick enough to hold micro servos, with direct connections to control surfaces.

Fuselage cross section is minimal, and there's just enough room for a 225 mah battery pack, RCD Micro 535 receiver, and two Futaba 133 servos. A wing loading of 8 to 12 oz/ft^2 yields a good flying machine. For the experimentally minded, Larry suggests enlarging the "Toucan" to 1.5 size — thus making it a "Threecan." We're contemplating building a "Fourcan."

A second project is a swept forward 'wing for the 60" span slope racing class. The airfoil for this yet to be named 'wing will be the SD 8020. Larry's construction method involves cutting the cores as though there is no sweep. Once the cores are cut, the sweep angle is cut into the planform. This thickens the wing section a bit, with the SD 8020 turning out to be about 9%

thick. Plans are currently being drawn utilizing CAD, and so should be very accurate.

Larry is also working on an advanced slope soaring book to be published by *Radio Control Modeler* magazine. Included will be a section on scale soaring gliders. While power scale slope soaring is very popular in Larry’s area, he has made a concerted effort to cover the truly powerless ’ships, too. We’re looking forward to publication!

Larry and the Toucan on a California slope.

Hartmut Siegmann's HS 3,0/9,0 and HS 3,4/12,0

The July 1992 issue of *Flug- und Modelltechnik* featured an article by Hartmut Siegmann which described a relatively light weight swept wing tailless design. Mr. Siegmann's goal was to construct an easily transported model which would be able to perform well in both light winds and, with a change of airfoil, flat land thermals.

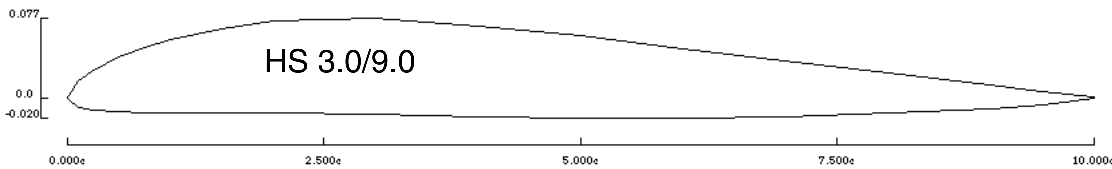
The result of Mr. Siegmann's work is a constant chord 'wing of 20 cm chord (about eight inches) and 1.5 meter wing span. For slope flying, a 3% section of 9% thickness is used. This gives sufficient lift with the minimum drag necessary for good penetration. A 12% thick 3.4% camber section is used for thermal flying. Twenty degrees of sweep and a moderate amount of twist is all that's needed to provide stability.

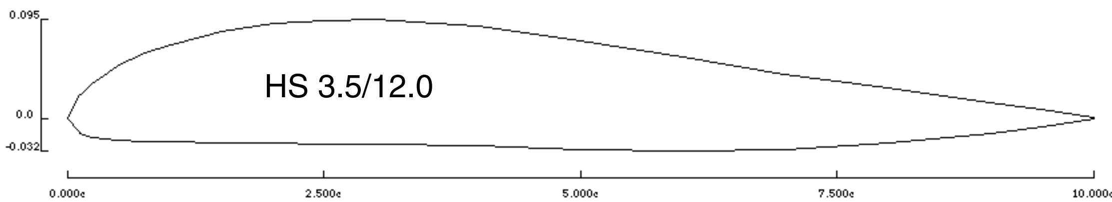
The airframe is built of foam and balsa, while paper packing tape serves as the covering material. (Thin balsa sheeting could be used if a more robust structure is desired.) An aluminum tube serves as the wing joiner, and winglets are glued on with five minute epoxy. A streamlined fuselage of sheet balsa completes the 'ship. This is a simple structure which is capable of very good performance. Mr. Siegmann's article included pictures of the completed model flying over the North Sea and in the Alps.

Coordinates for the HS 3,0/9,0 and HS 3,4/12,0 profiles were given in the article. We immediately entered this data into our plotting program, but the HS 3,0/9,0 which was produced showed some obvious flat spots when compared to the HS 3,4/12,0 contour. Some minor manipulations smoothed the profile nicely, and the resulting coordinates for both sections are printed here.

The accompanying chart gives the information you'll need to utilize these sections in your own design.

Section	Camber	Thickness	Zero Lift Angle, $\alpha_{l=0}$	Pitching Moment, C_m
HS 3,0/9,0	3.03%	9.37%	-1.21˚	0.00095
HS 3,4/12,0	3.51%	12.02%	-1.26˚	0.00001





HS 3.0/9.0	HS 3.5/12.0
100.000 0.100	100.000 0.100
95.000 0.640	95.000 0.812
90.000 1.240	90.000 1.475
80.000 2.443	80.000 2.870
70.000 3.624	70.000 4.250
60.000 4.750	60.000 5.902
50.000 5.975	50.000 7.516
40.000 7.000	40.000 8.901
30.000 7.685	30.000 9.500
20.000 7.425	25.000 9.415
15.000 6.753	20.000 9.099
10.000 5.627	15.000 8.380
7.500 4.900	10.000 7.120
5.000 3.925	7.500 6.271
2.500 2.685	5.000 5.140
1.250 1.770	2.500 3.500
0.000 0.000	1.250 2.330
1.250 -0.975	0.000 0.000
2.500 -1.175	1.250 -1.450
5.000 -1.335	2.500 -1.890
7.500 -1.430	5.000 -2.106
10.000 -1.475	7.500 -2.229
15.000 -1.500	10.000 -2.299
20.000 -1.540	15.000 -2.390
30.000 -1.685	20.000 -2.410
40.000 -1.900	25.000 -2.498
50.000 -2.000	30.000 -2.500
60.000 -2.000	40.000 -2.700
70.000 -1.875	50.000 -3.085
80.000 -1.520	60.000 -3.220
90.000 -1.040	70.000 -3.061
95.000 -0.650	80.000 -2.392
100.000 -0.100	90.000 -1.450
	95.000 -0.811
	100.000 -0.100

Ferdi Galè's "Ubãra"

The pitch stability of tailless planforms is always of concern to the designer. In the case of "plank" planforms, stability is achieved by reflexing the camber line of the airfoil from approximately c = 0.75 to the trailing edge. This change in airfoil contour affects the moment coefficient of the section, and the airfoil is self stabilizing when the coefficient is positive.

Swept 'wings, on the other hand, rely on washout - geometric, aerodynamic, or both - to achieve pitch stability. Four methods of determining the washout angle and twist distribution have been previously explored in this column. It is generally accepted, when speaking of swept tailless planforms, that a combination of more twist and a more forward CG create a more stable aircraft.

Our good friend Dr. Ing. Ferdinando Galè, author of "Tailless Tale," "Structural Dimensioning of Radioguided Aeromodels," and other books, described his experiences with a new tailless design in a recent letter.

"I am enclosing a picture of an experimental tailless I built recently. It is a free flight HLG which was intended to be a 'proof of concept' 'craft... to realize a larger radioguided version later on.

"The lifting area between the two vertical plates has a flat bottom airfoil set at four degrees, while the outboard stabilizing tips are just flat plates set at minus four degrees. The cuspidate tail, *a la* Horten, has a reflexed trailing edge. The initial idea was to alleviate the burden on the two stabilizing tips. The adjustable elevons, of thin aluminum, had to be set at neutral because Ubãra turned out to be ultra stable. The measured glide ratio is about 9:1, which is not bad for such a rough arrangement.

"Now the funny part of the story. After many hand launches, the tips were so damaged that I decided to tear them off before scrapping the model (that is, handing it to a young admirer, son of a neighbor). Then, big surprise! Without the stabilizing tips the model is as stable as with them. The glide path seems to be better, too.

"Perhaps if you mention this experiment in your 'On the 'Wing...' column, some keen readers may offer useful comments and suggestions."

Why did the removal of the wing tips not adversely affect Ubãra's flight performance? Was flight performance actually improved, and if so, why? How can this information be productively used in future designs? Ferdi's experiences with Ubãra certainly raise some interesting questions, and we would very much like to hear readers' thoughts.

Ubãra: Conclusions

In the August issue of *RCSD* we described a free flight HLG designed and built by Dr. Ing. Ferdinando Galè.

Ubãra, a swept wing design, featured an elongated root chord which formed a cuspidate (bat) tail. The root airfoil was a reflexed section. Ubãra's wing tips, which were flat plates, were set at -8 degrees to the root airfoil and separated from the main wing section by vertical plates. Ubãra flew very well in this original configuration, but flew better after removal of its wing tips.

We asked, in our column, for reader input regarding this change in flight performance. Nat Penton sent in what we consider the best explanation for the change in Ubãra's performance:

> "The extreme incidence settings of the outboard tips was trimming the wing to fly at a high CL with attendant high drag.
>
> "It is not surprising that removal of the tips resulted in better performance — lower profile drag and dramatically lower induced drag. It also provided some weight reduction and a CG shift in the desired direction. The L/D improvement should be dramatic.
>
> "A less dramatic comparison could have been made if the incidence of the tip plates was adjustable, although it would still be a more draggy arrangement than the final version."

Interestingly, none of the submitted explanations directly examined the effects of the reflexed center section on the glider's stability and subsequent performance. Rather, the focus seemed to be on the wing tips which were removed.

Ferdi's main point, and one which we attempted to reinforce, was to draw attention to a case where the chosen tailless planform and airfoil combination provides too much stability (and hence too much drag).

Ferdi stated, "The initial idea was to alleviate the burden on the two stabilizing tips. The adjustable elevons, of thin aluminum, had to be set at neutral because Ubãra turned out to be ultra stable... Without the stabilizing tips the model is as stable as with them. The glide path seems to be better, too."

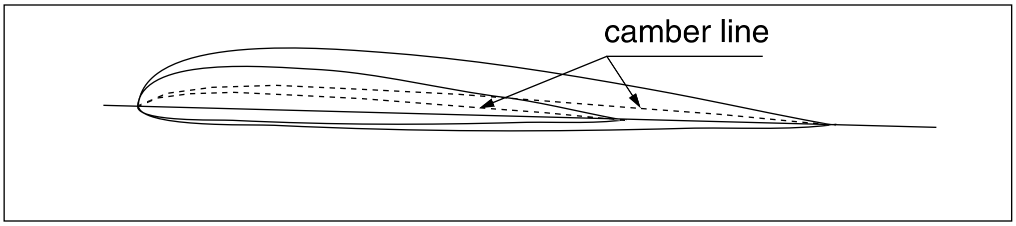


Figure 1

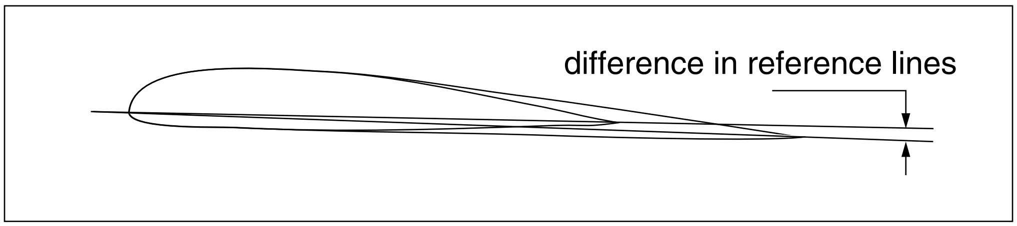


Figure 2

Thermaling is said to be improved by incorporating the bat tail configuration. But published reports have thus far described bat tails which are constructed by either simple enlargement of the entire root section (Figure 1) or by extension of the root section camber line well past the normal trailing edge (Figure 2). Notice how these methods affect the reference lines, and hence angles of attack, of the two sections. Since most modern high lift sections incorporate positive aft camber, bat tails have been a means of significantly improving lift, but at the same time increasing the wing's already strong negative pitching moment. This negative pitching moment must always be fully counteracted for stable flight.

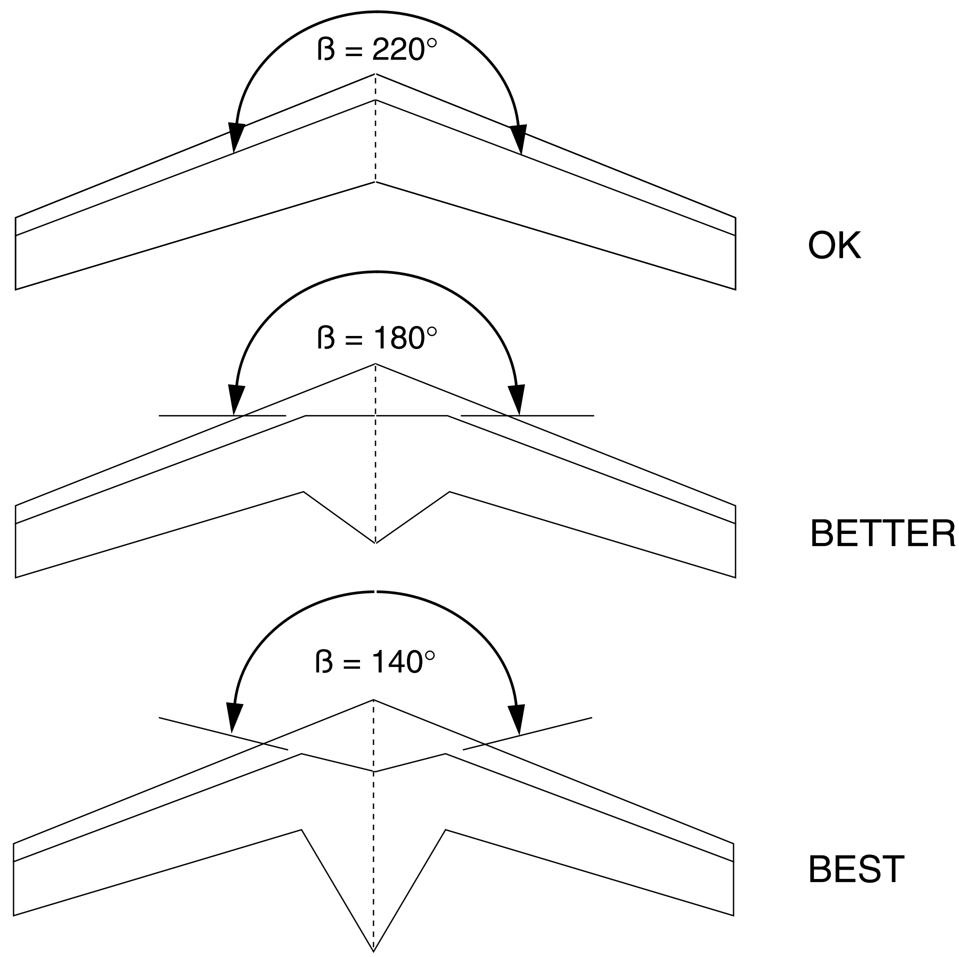
The bat tail of Ferdi's Ubãra, in contrast, was a negatively cambered surface. While this did not augment lift, the resulting planform did change the quarter chord line as promoted by the Hortens (Figure 3). But the combined effects of wing twist and negatively cambered bat tail proved detrimental to Ubãra's performance — using only one of these two means of achieving the required stability would have resulted in lower drag and better performance.

Did the reflexed center section alone contribute sufficient force to overcome the pitching moment of the entire wing? Ubãra did not pitch forward, but rather flew well following removal of the twisted wing tips, so in comparison to the normal practice of twisting both wing panels, a reflexed bat tail seems to be capable of providing sufficient stability.

Would Ubãra's performance have improved if Ferdi had simply retained the outer wing tip panels and changed the bat tail to the more usual positively cambered surface? We are not sure of the answer to this question. We tend to believe the twisted wing panels produced more drag than the reflexed bat tail. If this is so, the performance improvement, if any, would not have been so great as that seen in Ferdi's experience.

Given the choice of using wing twist or a reflexed bat tail, we would at this point tend to choose the reflexed bat tail. Based on Ferdi's experience with Ubãra, we think the reflexed bat tail option would yield superior results.

We certainly welcome further ideas and comments on this topic.



ß, the angle at which the quarter chord lines of the two wings meet at the center line, should be less than 180°, according to the Horten brothers.

Figure 3

Rise high within the wind's embrace
and ride one with nature.

— A. M. Pierce

Martin Hepperle's MH Sections for Tailless Aircraft

The following sections for tailless sailplanes were created a few years ago by Martin Hepperle. All require swept wing configurations, with the exception of the MH 61 which has a substantially positive pitching moment and could be used with a plank planform. In general, all are capable of creating greater lift with less drag than equivalent Eppler sections. All are designed for Reynolds numbers of 100,000 to 150,000 and higher; polars show excellent performance at Rn = 400,000.

The accompanying chart, along with Dr. Panknin's twist formula described in previous columns, can be used to determine suitable sections for a particular tailless planform.

MH 45

Along with the MH 44 and MH 46, neither of which is described here, the MH 45 was created for the Swiss LOGO-Team. The MH 45 is capable of very high lift while being slightly positively stable. It also has the advantage of being designed to benefit from the use of flaps (25% chord). With five degrees of deflection the maximum C_l is over 1.2, while with 10° of deflection it can achieve a maximum C_l of nearly 1.6, according to published polars. The MH 45 is just over 9.8% thick, and should receive serious consideration when looking for a root section.

MH 60

The MH 60 was designed to be an improvement over the Eppler 182, a very good section in its own right. The MH 60 is easily capable of producing a C_l of 0.65, while its maximum C_l is about 1.0; these values are about 0.2 higher than those of the Eppler 182. The MH 60 appears to be a better choice for a tip section than the Eppler 228. The minimum Reynolds number for the MH 60 is 150,000.

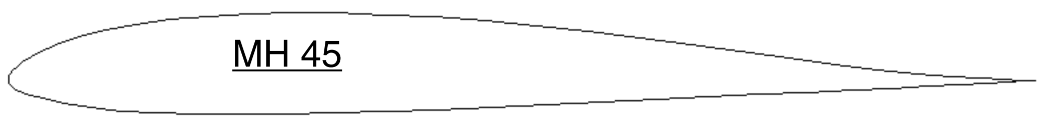
MH 61

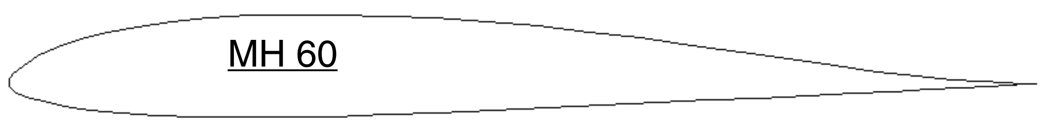
This section's performance is also comparable to that of the Eppler 228. The MH 61 should be used with tailless swept wings having a minimum of twist; it may also be used with plank planforms, as we mentioned previously. Minimum Reynolds number for the MH 61 is 150,000.

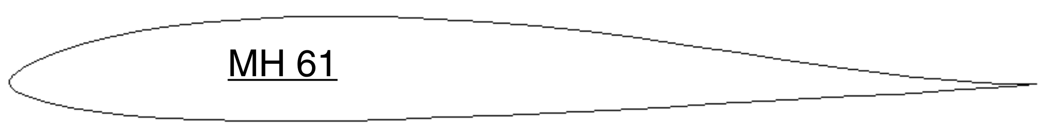
MH 62 and MH 64

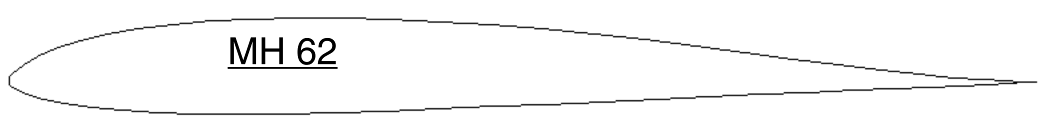
These two sections have no Eppler equivalents. They can tolerate lower Reynolds numbers than the MH 60 and MH 61 — down to Rn = 100,000.

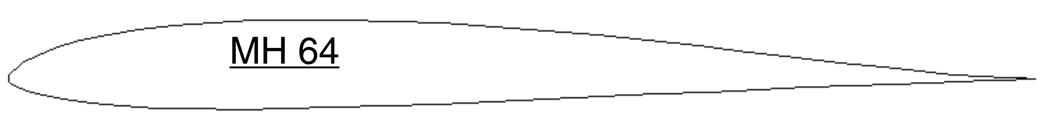
Section	Zero Lift Angle, $a_{l=0}$	Pitching Moment, C_m	Thickness at %c	Camber at %c
MH 45	0.370	0.0058	9.84	
MH 60	0.420	0.0051	10.08 at 27.20	1.76 at 38.10
MH 61	-0.107	0.0175	10.28 at 29.90	1.48 at 38.10
MH 62	-0.520	-0.0004	9.30 at 26.90	1.60 at 37.00
MH 64	-0.600	-0.0050	8.61 at 26.90	1.60 at 38.80











MH45		MH 60		MH 61		MH 62		MH 64	
1.00000	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
0.99669	-0.00010	0.99666	-0.00011	0.99662	-0.00021	0.99672	-0.00006	0.99678	-0.00002
0.98669	-0.00021	0.98657	-0.00023	0.98634	-0.00059	0.98684	-0.00005	0.98709	0.00007
0.97013	0.00016	0.96984	0.00014	0.96923	-0.00048	0.97051	0.00042	0.97110	0.00060
0.94746	0.00130	0.94692	0.00134	0.94584	0.00055	0.94812	0.00163	0.94916	0.00178
0.91917	0.00332	0.91828	0.00354	0.91671	0.00267	0.92011	0.00371	0.92168	0.00374
0.88574	0.00629	0.88452	0.00691	0.88248	0.00606	0.88703	0.00681	0.88915	0.00661
0.84775	0.01028	0.84641	0.01148	0.84394	0.01072	0.84956	0.01096	0.85224	0.01039
0.80590	0.01536	0.80469	0.01708	0.80189	0.01650	0.80842	0.01602	0.81159	0.01497
0.76107	0.02140	0.76008	0.02350	0.75708	0.02313	0.76428	0.02179	0.76785	0.02018
0.71405	0.02803	0.71329	0.03043	0.71024	0.03031	0.71781	0.02802	0.72166	0.02580
0.66547	0.03488	0.66497	0.03752	0.66204	0.03762	0.66965	0.03440	0.67365	0.03155
0.61587	0.04154	0.61566	0.04434	0.61302	0.04455	0.62035	0.04055	0.62436	0.03712
0.56569	0.04768	0.56577	0.05056	0.56351	0.05077	0.57033	0.04619	0.57426	0.04224
0.51532	0.05306	0.51568	0.05594	0.51386	0.05605	0.52002	0.05110	0.52377	0.04672
0.46516	0.05755	0.46575	0.06037	0.46445	0.06025	0.46981	0.05515	0.47331	0.05044
0.41564	0.06108	0.41641	0.06378	0.41565	0.06329	0.42012	0.05830	0.42334	0.05335
0.36723	0.06358	0.36813	0.06615	0.36787	0.06513	0.37146	0.06051	0.37436	0.05541
0.32039	0.06498	0.32138	0.06741	0.32154	0.06577	0.32431	0.06171	0.32685	0.05655
0.27558	0.06523	0.27662	0.06751	0.27709	0.06518	0.27913	0.06186	0.28130	0.05674
0.23318	0.06425	0.23426	0.06640	0.23491	0.06336	0.23633	0.06089	0.23814	0.05591
0.19353	0.06203	0.19465	0.06405	0.19534	0.06033	0.19629	0.05879	0.19773	0.05402
0.15691	0.05862	0.15809	0.06048	0.15870	0.05614	0.15933	0.05557	0.16043	0.05109
0.12363	0.05410	0.12468	0.05576	0.12523	0.05090	0.12573	0.05127	0.12651	0.04717
0.09395	0.04858	0.09521	0.05000	0.09521	0.04481	0.09577	0.04600	0.09626	0.04233
0.06813	0.04218	0.06937	0.04331	0.06892	0.03804	0.06965	0.03985	0.06990	0.03666
0.04634	0.03500	0.04750	0.03581	0.04659	0.03077	0.04755	0.03293	0.04761	0.03028
0.02867	0.02722	0.02965	0.02769	0.02843	0.02321	0.02954	0.02544	0.02947	0.02335
0.01520	0.01906	0.01589	0.01929	0.01457	0.01560	0.01568	0.01766	0.01555	0.01614
0.00588	0.01088	0.00625	0.01098	0.00514	0.00829	0.00602	0.00997	0.00589	0.00902
0.00079	0.00326	0.00086	0.00335	0.00031	0.00184	0.00067	0.00297	0.00059	0.00257
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00068	-0.00279	0.00063	-0.00268	0.00134	-0.00348	0.00067	-0.00261	0.00078	-0.00260
0.00641	-0.00788	0.00634	-0.00782	0.00856	-0.00857	0.00660	-0.00749	0.00690	-0.00724
0.01781	-0.01310	0.01760	-0.01307	0.02097	-0.01389	0.01793	-0.01248	0.01830	-0.01200
0.03421	-0.01814	0.03387	-0.01809	0.03826	-0.01907	0.03423	-0.01724	0.03463	-0.01653
0.05531	-0.02277	0.05490	-0.02265	0.06019	-0.02391	0.05525	-0.02157	0.05566	-0.02064
0.08085	-0.02678	0.08046	-0.02657	0.08653	-0.02818	0.08080	-0.02526	0.08120	-0.02414
0.11065	-0.02991	0.11036	-0.02968	0.11707	-0.03174	0.11067	-0.02817	0.11105	-0.02686
0.14460	-0.03206	0.14441	-0.03191	0.15158	-0.03446	0.14468	-0.03021	0.14504	-0.02873
0.18252	-0.03329	0.18237	-0.03323	0.18982	-0.03631	0.18261	-0.03137	0.18293	-0.02974
0.22408	-0.03366	0.22396	-0.03370	0.23147	-0.03729	0.22416	-0.03171	0.22445	-0.02995
0.26891	-0.03330	0.26880	-0.03342	0.27618	-0.03741	0.26897	-0.03132	0.26922	-0.02946
0.31654	-0.03229	0.31644	-0.03249	0.32357	-0.03676	0.31656	-0.03030	0.31678	-0.02836
0.36646	-0.03073	0.36637	-0.03101	0.37317	-0.03545	0.36646	-0.02876	0.36665	-0.02677
0.41816	-0.02875	0.41806	-0.02908	0.42447	-0.03361	0.41813	-0.02681	0.41829	-0.02478
0.47104	-0.02646	0.47094	-0.02684	0.47691	-0.03137	0.47098	-0.02458	0.47112	-0.02255
0.52449	-0.02399	0.52438	-0.02441	0.52987	-0.02886	0.52441	-0.02217	0.52452	-0.02017
0.57786	-0.02143	0.57774	-0.02188	0.58271	-0.02619	0.57775	-0.01971	0.57785	-0.01775
0.63049	-0.01888	0.63036	-0.01933	0.63480	-0.02345	0.63036	-0.01725	0.63044	-0.01539
0.68174	-0.01640	0.68160	-0.01684	0.68549	-0.02070	0.68159	-0.01488	0.68166	-0.01311
0.73095	-0.01403	0.73082	-0.01444	0.73417	-0.01799	0.73081	-0.01262	0.73087	-0.01098
0.77754	-0.01179	0.77743	-0.01217	0.78024	-0.01537	0.77742	-0.01052	0.77747	-0.00902
0.82094	-0.00971	0.82085	-0.01006	0.82314	-0.01288	0.82084	-0.00859	0.82089	-0.00725
0.86062	-0.00782	0.86054	-0.00814	0.86235	-0.01055	0.86055	-0.00687	0.86059	-0.00570
0.89607	-0.00613	0.89601	-0.00642	0.89737	-0.00841	0.89602	-0.00535	0.89607	-0.00437
0.92686	-0.00465	0.92681	-0.00489	0.92776	-0.00646	0.92683	-0.00404	0.92688	-0.00325
0.95259	-0.00334	0.95255	-0.00353	0.95315	-0.00469	0.95258	-0.00290	0.95263	-0.00230
0.97293	-0.00219	0.97290	-0.00233	0.97321	-0.00310	0.97294	-0.00190	0.97300	-0.00150
0.98770	-0.00113	0.98767	-0.00121	0.98777	-0.00161	0.98771	-0.00098	0.98777	-0.00077
0.99683	-0.00031	0.99682	-0.00033	0.99683	-0.00044	0.99684	-0.00026	0.99687	-0.00021
1.00000	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000

*The time will come when thou shalt lift thine eyes
to watch a long drawn battle in the skies
while aged peasants too amazed for words
stare at the flying fleets of wondrous birds.*

— Thomas Gray, 1737

Rudder Differential Revisited

Our February 1992 column (also in “On the’Wing… the book”) explored some of the details involved in Gregory Vasgerdsian’s building of a scale model of the Storch IV, a swept wing tailless design of the late 1920s which has rudders mounted at the end of each wing tip. Ideally, the inboard rudder should move outward during a turn, while the outboard rudder remains in its neutral position. One of the problems Greg encountered during the pre-building stage was finding a simple but effective method of achieving this maximum rudder differential without relying on a computer radio.

Figure 1 shows the simple cable mechanism we described in that February 1992 column. A small spring or rubber band forces the rudder against a stop at the neutral position. The cable then pulls against the spring and moves the rudder outward, but slips when it pushes. Rudder movement is thus in one direction only. There is an inherent conflict in this set-up: the spring or rubber band must be strong enough to hold the rudder firmly against the stop, while the servo must be strong enough to overcome both this force and the air loads imposed on the deflected rudder.

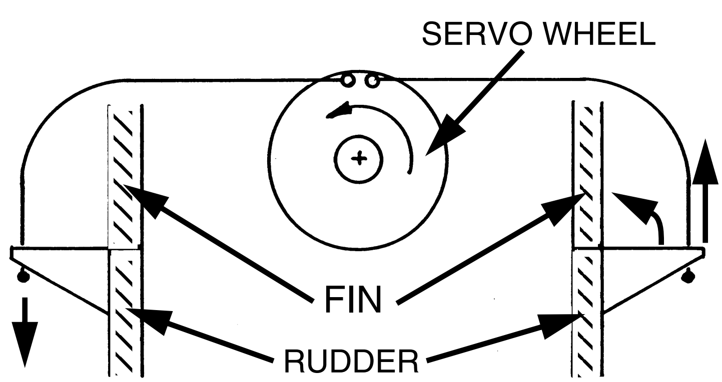


Figure 1

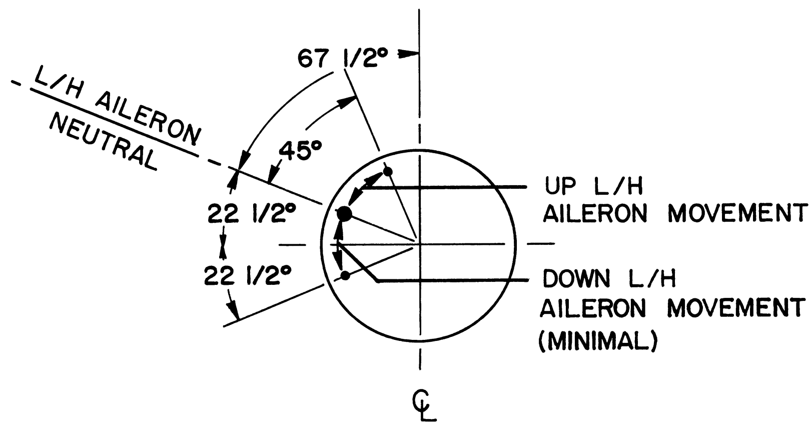


Figure 2

A rigid mechanism which overcomes these failings was submitted by our Minnesota friend Bill Kubiak. This system, presented in the September 1992 issue of *RCSD*, uses stiff pushrods and relies on servo wheel geometry to achieve differential action. This set-up is shown in Figure 2. When properly built, the mechanism allows no extraneous rudder movement, as the rudder is locked in the neutral position by the servo wheel. This rigidity makes the system less likely to flutter.

Bill Foshag, of Carlisle Pennsylvania, recently sent a packet of information to us which included a means of achieving maximum rudder differential by means of a "walking beam." The walking beam mechanism itself, shown in Figure 3, appears to be easily constructed and quite robust. (In the accompanying letter, Bill relates its successful use in a centrifugal field!) It has the additional advantage of being able to be placed remote from the single servo needed to drive it. The walking beam's role in providing 100% - 0% differential to outboard rudders is covered by a U.S. Patent given to Bill and Gabriel D. Boehler in 1966. That Patent (3,2662,656) is now in the public domain.

The walking beam mechanism consists of three interconnected beams. Beams A and B are connected by a movable joint, as are beams B and C. The beam ends A' and C' are mounted to the mixer frame, and the servo pushrod is connected to the center of beam B. The movement of joint A-B is limited by pin E, and that of joint B-C by pin F. As the servo pulls beam B, the joint A-B is held in place by pin E, and the joint B-C moves in the same direction as that of the servo pushrod. When beam B is pushed by the servo, the joint A-B moves away from pin E and the joint B-C is restrained by pin F.

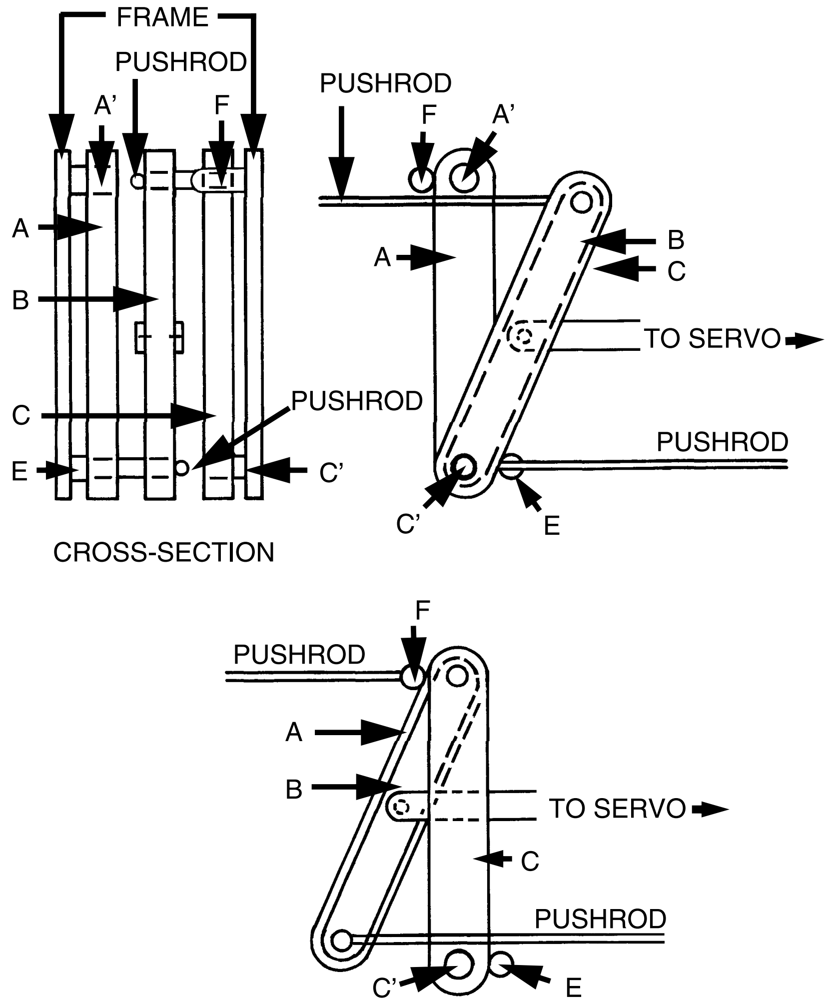


Figure 3

It should be noted the geometry of this walking beam magnifies the movement of the servo pushrod - a lever effect which places a proportionally larger load on the servo - so care should be exercised in the choice of the servo used. By adjusting the placement of pins E and F and the control surface pushrods, it should be possible to create a situation where the control surface is locked in the neutral position by a “toggle-over-center” action.

Make a mock-up of a walking beam mechanism from popsicle sticks. This will familiarize you with all the intricacies of operation with very little cost. You will find, once a mock-up is made, that it is extremely important to line up the holes with the center of each arm. Lastly, sweep may affect the overall geometry of the walking beam. This may not be a problem if the walking beam pulls cables, but will be a critical issue if pushrods are used.

The walking beam shown in Figure 3 is a generic device, and this drawing should be used as a guide only. Materials and specific methods of construction are left to the builder. Plywood, plastic, or metal could be used. In fact, a small device consisting of three modified nylon bellcranks is an attractive alternative. No matter the construction method or materials used, a substantial load test needs to be successfully completed before the device is installed in an aircraft.

As mixers of various types are always of interest to *RCSD* readers, we invite individuals building a walking beam mechanism to provide construction details.

The Fauvel AV 36

Jim Gray, our good friend and long time correspondent, is an experienced pilot of full sized sailplanes and an enthusiastic supporter of tailless planforms. This enthusiasm for “flying wings” dates back to 1958 and a soaring flight at Harris Hill, Elmira New York.

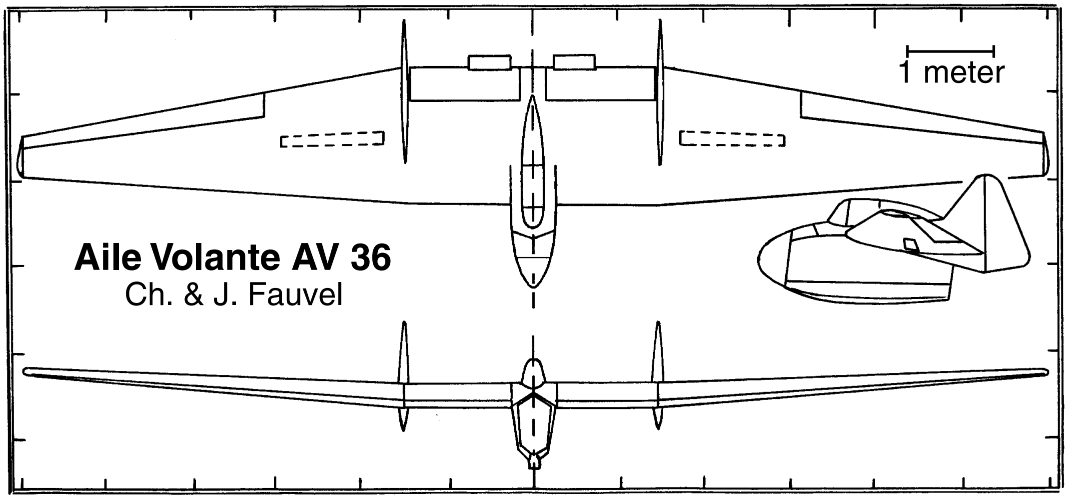
It was during the Snowbird contest of that year Jim flew his Schweizer 1-20 in the company of a Fauvel AV 36 which had been brought to the event from Montreal. While the performance of the AV 36 was a bit better than the Schweizer’s, the Canadian pilot was apparently not accustomed to ridge soaring, and so the two gliders were fairly well matched. Flying wing-and-wing with the tailless AV 36 was, for Jim, an intriguing and at the same time overwhelming experience.

When Jim related this event in a recent letter we immediately went to our files and began gathering information. As you will see, the AV 36 makes a nearly ideal subject for scale modeling.

Charles Fauvel was a firm believer in the simple “plank” planform as an alternative to the rather complicated swept wing designs of the Horten brothers. Fauvel argued the plank was easier and less expensive to build, and the completed sailplane, because of its conventional control system, would be easier to fly. His first design, the AV 3, appeared in the early 1930s. Development of the AV 36 probably started prior to 1948. Jean Fauvel, Charles’ son, completed the prototype at the end of 1951, with the first flight on December 31.

AV 36 flight performance, when compared with conventional designs of the time, is very good. It has a glide ratio between 24:1 and 26:1, a stall speed of about 30mph., and a maximum speed of around 124mph.

As can be seen from the accompanying 3-view, the center section is a simple rectangle while the outer panels are of tapered planform. The panels are separated by the fin/rudder assemblies. The wing of the AV 36 was designed so the spar is a straight line from wing tip to wing tip. The leading edge sheeting is bonded to the spar to form a D-tube, while the remainder of the wing is of open construction with fabric covering. Controls consist of ailerons, elevator, and rudder, with the twin rudders having differential



movement. The fuselage is a simple polygon. One bulkhead is attached to the main spar, effectively integrating the fuselage and wing.

The AV 36 is unique not only because of its tailless planform, but also because of its transportability. The nose cone is removed and the rudders are fully deflected and bolted to the trailing edge of the wing. Placed on its trailer, one wing extends over the towing vehicle and the entire sailplane travels down the highway sideways in what is essentially one piece.

Model builders can construct a rather large model which disassembles into three easily manageable pieces - the center section and the right and left outer wing panels. The fins can be made to slide off as well.

Readers interested in constructing and flying a replica of the AV 36 have a couple of options.

Plans for a 1/4 scale three meter span model are available from Verlag für Technik und Handwerk GmbH, Postfach 1128, Fremersbergstr. 1, 76492 Baden-Baden 1, Germany. The cost is DM 53,-, plus DM 6,- for shipping.

Plans for a larger version, in 3.45 scale, are available from Argus Plans Service. These plans cost £18.45, including shipping, and detail two versions of the AV 36. The construction article, along with five pages of documentation material, appeared in the Spring '92 issue of *Silent Flight*. Having a copy of this magazine is a must for builders of an AV 36 model. Contact *Silent Flight*, Argus Specialist Publications. The plans service and the publications section share the same address: Argus House, Boundary Way, Hemel Hempstead, Hertfordshire HP2 7ST, England.

The designer of the latter model, the late Gordon Waite, used the CJ 3309 airfoil, but performance could be improved by using the CJ $25^2$09. The

CJ 25^{2}09 has the added benefit of more closely resembling the Fauvel F2 airfoil of the full size sailplane. This change of airfoil does not affect either construction materials or methods. However, we note Gordon built three degrees of washout into the wing tips and then added permanent up trim to the elevator. This design requires no washout, and if the wing is built without washout the up trim can be removed from the elevator. This will markedly improve its already good performance.

The AV 36 in model form exhibits the same good flying characteristics as its full sized relative. The conventional control system uses simple radio gear and allows pilots to easily transition to a tailless configuration. The location of the tow hooks makes for easy winch launching and aero towing. Whether flown from a slope or over flat land, the AV 36 is sure to provide good performance and attract positive attention.

An AV 36 at a meet in England. Photo courtesy of Eric Marsden.

"The application of an additional bearing surface, as a tail, is of minor importance."

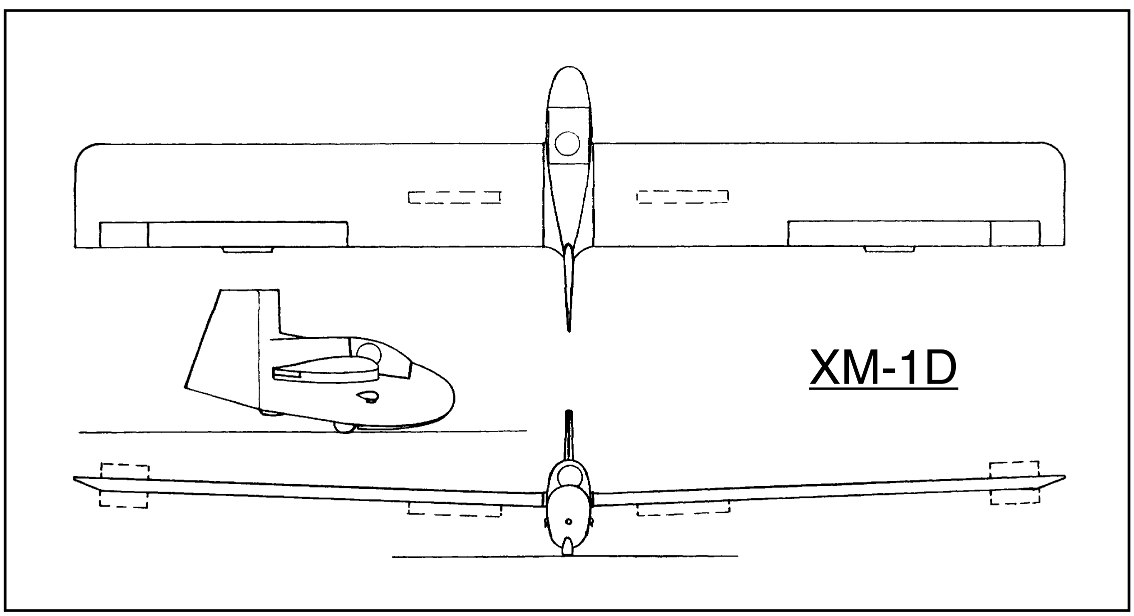
— Otto Lilienthal
Der Vogelflug als Grundlage der Fliegekunst, 1889

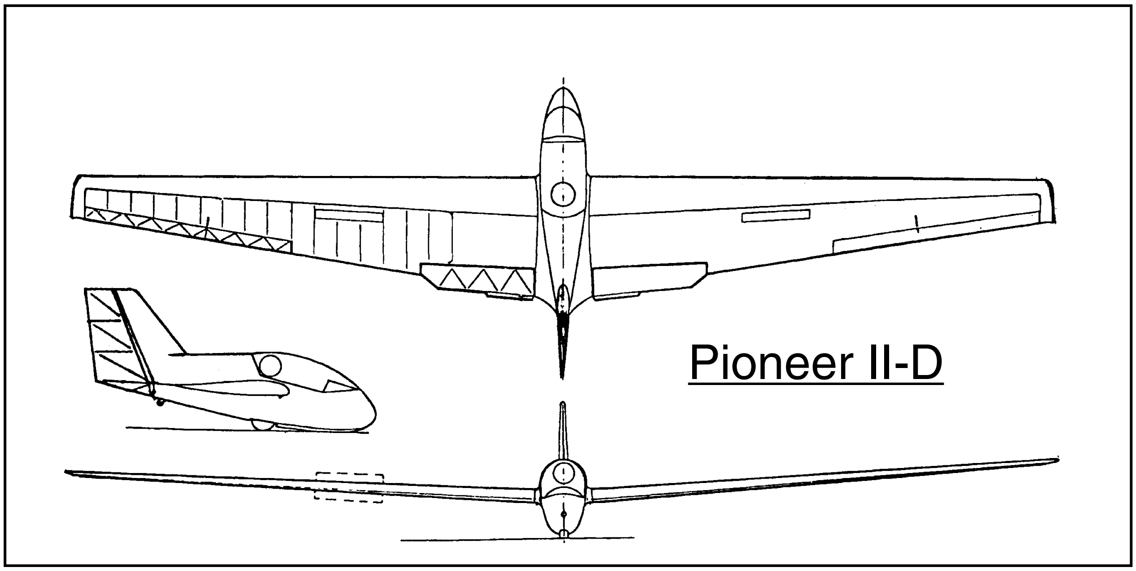
Jim Marske's "Pioneer II-D"

The "Pioneer II-D" story began in 1953 when Jim Marske read an article about Charles Fauvel's AV 36. Fascinated by the report of a successful tailless sailplane, Jim built and flew a model which exhibited the same positive attributes as the full size version. In 1954 Jim read about A1 Backstrom's EPBI-A. A scale model of this Backstrom design performed in equivalent fashion to the Fauvel model. What impressed Jim about the tailless planform was its uncanny ability to recover from pitch upsets with minimum loss of altitude.

Encouraged by his success with the two scale models, Jim began working on his own version of a tailless sailplane, and when an eight foot span model showed excellent performance, construction of a full sized tailless sailplane began in earnest.

Four versions of a constant chord planform were eventually built and flown, designated XM-1, XM-1B, XM-1C, and XM-1D. From an appearance standpoint, the most visible changes which appeared during this evolution were the removal of the two tip fins and placement of a single fin on the rear of the fuselage, and significant streamlining of the fuselage itself. Roll and pitch for the XM-1 series consistently involved use of elevons; but drag





rudders were added outboard of the elevons on the D model. Performance of the XM-1D was exceptional for a sailplane of just 40 foot wing span - it had a glide ratio of 30:1 at 57 mph.

In order to eliminate some of the problems associated with the constant chord wing, Jim adopted a tapered planform for the Pioneer series. Rather than sweep the wing back, however, he swept it forward, resulting in a wing with a straight leading edge. The benefits include a forward CG which increases the elevator moment, an ability to use aileron differential without adverse pitch effects, and an inhibition of spanwise airflow at high angles of attack. In addition, the Fauvel airfoil which had been used up to this time was abandoned in favor of the NACA 23112-75 because of its higher maximum coefficient of lift and lower drag.

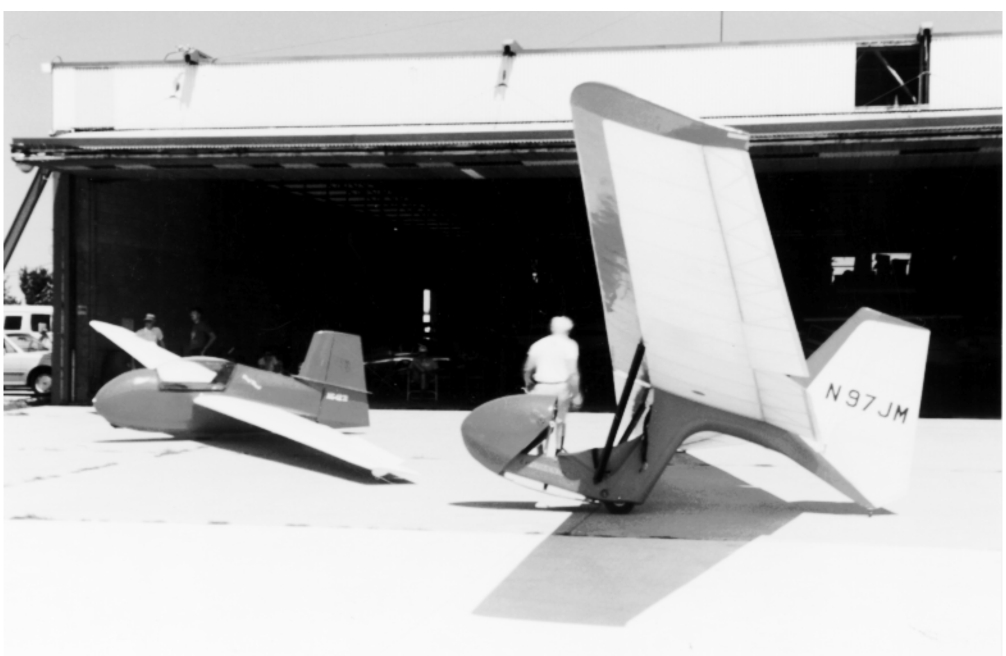
The Pioneer I first flew in March of 1968. Impressed with its performance but seeing needed improvements, modifications were made. The design became the Pioneer IA and flew in August 1968. The Pioneer IA has some striking similarities to the Schweizer 1-26: the total wing and stabilizer area of the 1-26 is equal to the wing area of the Pioneer; the airfoils used in the two 'ships are from the same family; the aspect ratios are about the same; both fuselages are of similar construction and aerodynamics. Despite these similarities, the Pioneer's performance was superior. Minimum airspeed for the Pioneer IA was 32.5 mph, and minimum sink was at 46 mph. The maximum glide ratio was 35:1 at 57.5 mph, and speeds of over 100 mph were easily obtained despite a wing loading of just 3.3 Ibs./ft^2. To give an idea of performance potential, consider these achievements... The Pioneer IA flew a goal and return flight of 216 miles in 3 1/2 hours, averaging 62 mph.; it reached an altitude of 31,000 feet in the Pikes Peak wave; it was flown as fast as 162 mph without any indication of flutter.

The adoption of a fiberglass fuselage and installation of ailerons and true air brakes separates the Pioneer II from its predecessors. The "Pioneer II-D", the latest version, spans 13 meters (42.6') and has a wing loading of 4.4 Ibs./ft^2 fully loaded. Available as a kit, it can be built and stored in a standard 22' garage.

Scaled to 1/4 of full size, the "Pioneer II-D" has much to offer the modeler. It is of reasonable dimensions and is easily transported. Our own model climbed easily and steadily in a thermal without circling, a characteristic identical to its full sized counterpart. It was also capable of both loops and rolls. Since the controls are identical to conventional sailplanes (ailerons, elevator, rudder and air brakes), there is very little difficulty in making the transition from conventional to tailless flight.

We sold our "Pioneer II-D" to a modeler in Seattle, but have recently considered building another. With dual tow hooks mounted on the CG, winch launches and aero tows should be relatively hassle free. We would very much like to try the latter method of getting to altitude, particularly with an unconventional design like the Pioneer. Who knows, perhaps you'll see us with a new "Pioneer II-D" at a future scale event.

Most of the information for this column came from "Experiment in Flying Wing Sailplanes" by Jim Marske. Copies are available directly from Jim at Marske Aircraft Corporation, 130 Crestwood Drive, Michigan City IN 46360. At least two full sized Pioneer II sailplanes are currently flying in the United States, and one in Canada.



Bernie Gross' Pioneer II-A and Jim Marske's Monarch at Bryan Ohio.

Andrew MacDonald’s “screen saver.”

Hermann Zahlmann's "Horten XV Mod."

It is always of great interest to examine a model in light of the designer's stated goals, and Mr. Zahlmann had a number of goals in mind when he designed his "Horten XV mod." He wanted a good looking, inexpensive, easily transported tailless sailplane. It had to be stable in flight, controllable and quick (but not frantic), and suitable for both thermal and slope flying. A simple RC installation and easy field assembly were also desirable characteristics.

The result is a 2.4 meter span swept 'wing of wood construction with fabric covering which fulfills all of Mr. Zahlmann's objectives. The "Horten XV mod." disassembles into three easily handled pieces which conveniently fit into the trunk of a medium sized car. The center section is large enough for the insertion of ballast, and the servos are mounted in the wings with direct connections to the elevons. While not an ideal thermaling sailplane, as it is a bit too fast, it has competed successfully with conventional tailed designs. Launches using a high-start made of 30 meters of rubber and 150 meters of line result in flight times of three to five minutes.

Mr. Zahlmann incorporated several novel construction methods in the building of this model:

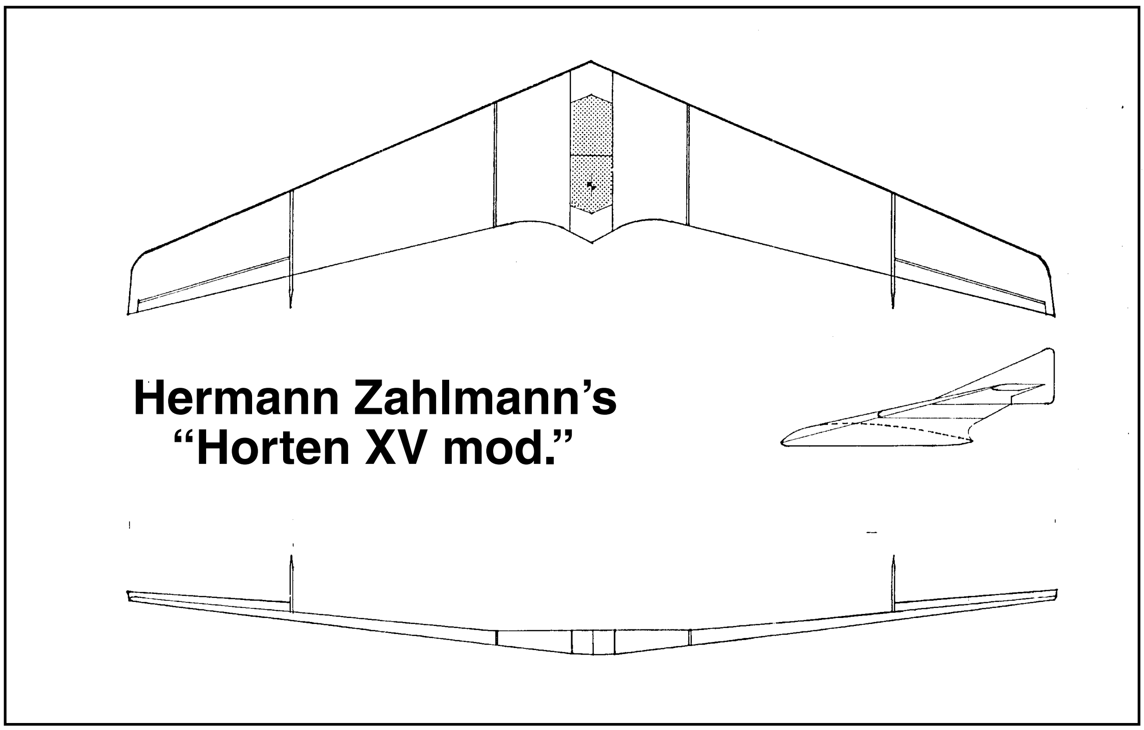
- The center section is built inverted, with the upper surface on the building board. Jig blocks hold the leading and trailing edge and prevent the wing from rocking. When completed, the top of the center section is flat and the lower surface provides a small amount of dihedral.

- The airfoil section used at the center line has some reflex, and the cuspidate tail is formed so the trailing edge is a straight line when viewed from the rear.

- Other than the center line section, all ribs utilize the Clark Y section. Stability is provided by inverting the panels outboard of the fins and incorporating an appropriate amount of washout. A rather ingenious construction method accomplishes this. The outer panels of the wing are built in the usual way, with the flat bottom of the ribs placed directly on the building board, but the spars are assembled with the wing rod tubes very carefully placed. When completed, the outer wing tips are sawed free and exchanged. The right panel is thus inverted and placed on the left wing, and the left panel is inverted and placed on the right wing. The correct amount of washout, about eight degrees, is automatically achieved when the panels are inverted and attached to the main wing with the wing rods in place.

- The fins serve as fences, separating the two wing panels. This is a good way of handling the junction where there is a drastic change in contour, and the efficiency of both the lifting surface and the stabilizing surface is greatly improved. Holes in the fins allow the wing rods to pass through, and the fins are then held in place by pressure from the two wing panels.

The "Horten XV mod." has fulfilled all of Mr. Zahlmann's stated design goals and offers several innovative construction methods.



Hermann Zahlmann's "Horten XV mod."

Jef Raskin's "Max Plank"

Jef Raskin is no stranger to the pages of *RC Soaring Digest*. His articles on slope aerobatics have provided information on the current state of this event, and have stimulated both thought and further discussion. Jef's aerobatic design, the "Anabat 2," has been described and advertised in *RCSD*, and is available from Anabatic Aircraft and Northeast Sailplane Products. Recent correspondence from Jef included information about a modification of the "Anabat 2" to a tailless design. Here's what Jef had to say about the resulting "Max Plank" design.

"My son and I have been enjoying a flying wing that we call the 'Max Plank.' It is small, with a span of 36", a chord of 8", and a rectangular planform. It uses aileron-elevator mixing at the transmitter and the usual elevon setup, and flies very well in a wide range of lift.

"This 'wing is hands-off stable. I made one for my 5 year old daughter as a free flight model. She tosses it around - even off the slope where we do R/C soaring - and it always quickly resumes straight and level flight, however bad the launch, so long as there is at least four or five feet of altitude.

"Anybody who thinks that a plank cannot be both very stable and very aerobatic should fly one of these. Rolls are very easy in the 'Max Plank' by simply putting the stick hard over. With the elevons having 25% of the area of the wing and large throws (30 degrees), rolls make the 'plane look like a propeller. Loops are best at large radius, as pulling up too tightly results in a high-frequency oscillation of the airplane in straight ahead flight. This stops when back pressure is released.

"The day before yesterday I was out slope soaring my four channel Anabat 48 and my son Aza, now 9, was flying his 'Max Plank.' I was working on spins (seeing how flat I could get them) and he was practicing landings. His first two landings were good, but on the third landing he slammed it into a rock outcrop with a crash loud enough to make everybody look. I was sure something was broken, but all that had happened was that one wing leading edge corner was pushed in about a sixteenth of an inch, leaving its flying qualities unaffected.

"Here are the coordinates of the airfoil for scratch-builders. Since it is symmetrical, only one surface is given. The coordinates have not been published previously.

"I designed the WE3008 airfoil by a long string of gradual improvements. A number of fliers have built flying wings with this airfoil, some planks like mine, most of them with taper and/or sweep. They have all flown well.

"The airfoil is the same symmetrical WE3008 that I use on my Anabat line of slope soarers, so its inverted performance is as good as its upright performance. This section is 8% thick with no camber; as for any symmetrical section, the pitching moment is zero and the zero lift angle is 0 degrees. In practice the elevons are very slightly reflexed. Beginners use a further forward C.G. and more reflex, more expert fliers move the C.G. back and use almost no reflex.

"It is easy to turn an Anabat 2 kit into one of these wings. Just cut off the fuselage 10" behind the trailing edge of the wing, taper the rear portion of the fuselage, attach the fin at the top of the end of the shortened fuselage, eliminate the stabilizer, and place the two servos side-by-side to operate the ailerons as elevons.

"I can build a 'Max Plank' in about three hours. Like the Anabats, it is nearly indestructible. It is also very convenient to carry to the field since it will fit on the ledge behind the back seat in most cars without any disassembly. Actually, it is impossible to disassemble since it is built in one piece. The 'Max Plank' has become my standard 'plane-that-is-always-in-the-car,' and I feel free to try to fly it almost anywhere."

The "Max Plank" is a rugged, inexpensive, easily built 'ship for slope flying. Whether you are a newcomer to the slope or an advanced flyer looking for something a bit different, the "Max Plank" should serve you well.

Anabatic Aircraft, 8 Gypsy Hill Road, Pacifica CA 94044.

Northeast Sailplane Products, 16 Kirby Lane, Williston VT 05495.

WE3008

X	Y
0.000	0.00000
0.001	0.00326
0.002	0.00461
0.003	0,00564
0.004	0.00651
0.006	0.00796
0.008	0.00918
0.010	0.01024
0.012	0.01120
0.015	0.01249
0.020	0.01436
0.025	0.01598
0.030	0.01743
0.035	0.01875
0.040	0.01995
0.050	0.02211
0.060	0.02400
0.070	0.02568
0.080	0.02719
0.090	0.02857
0.100	0.02982
0.120	0.03200
0.140	0.03384
0.160	0.03538
0.180	0.03666
0.200	0.03771
0.220	0.03855
0.260	0.03964
0.300	0.04000
0.350	0.03944
0.400	0.03771
0.450	0.03478
0.500	0.03162
0.550	0.02846
0.600	0.02530
0.650	0.02214
0.700	0.01898
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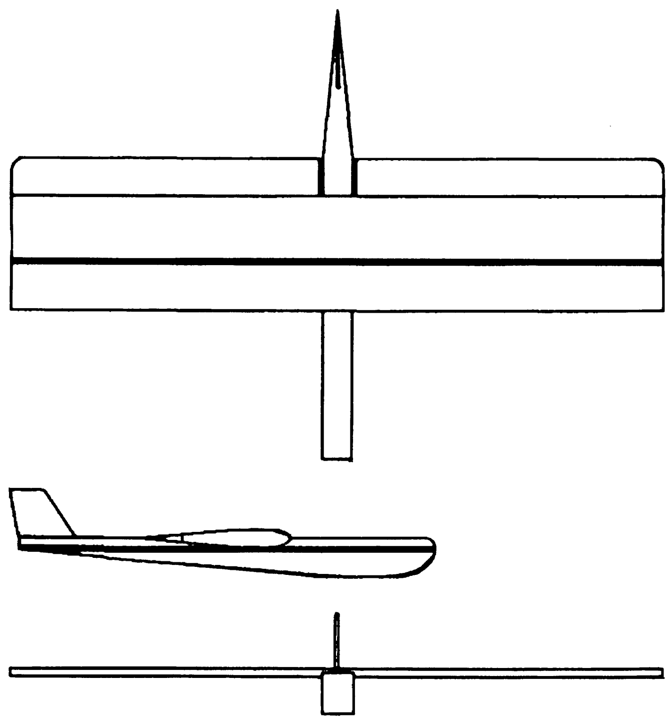
0.850	0.00949
1.000	0.00000



Jef Raskin's "Max Plank"

When once you have tasted flight,
you will forever walk the earth
with your eyes turned skyward,
for there you have been, and there
you will always long to return.

— Leonardo da Vinci

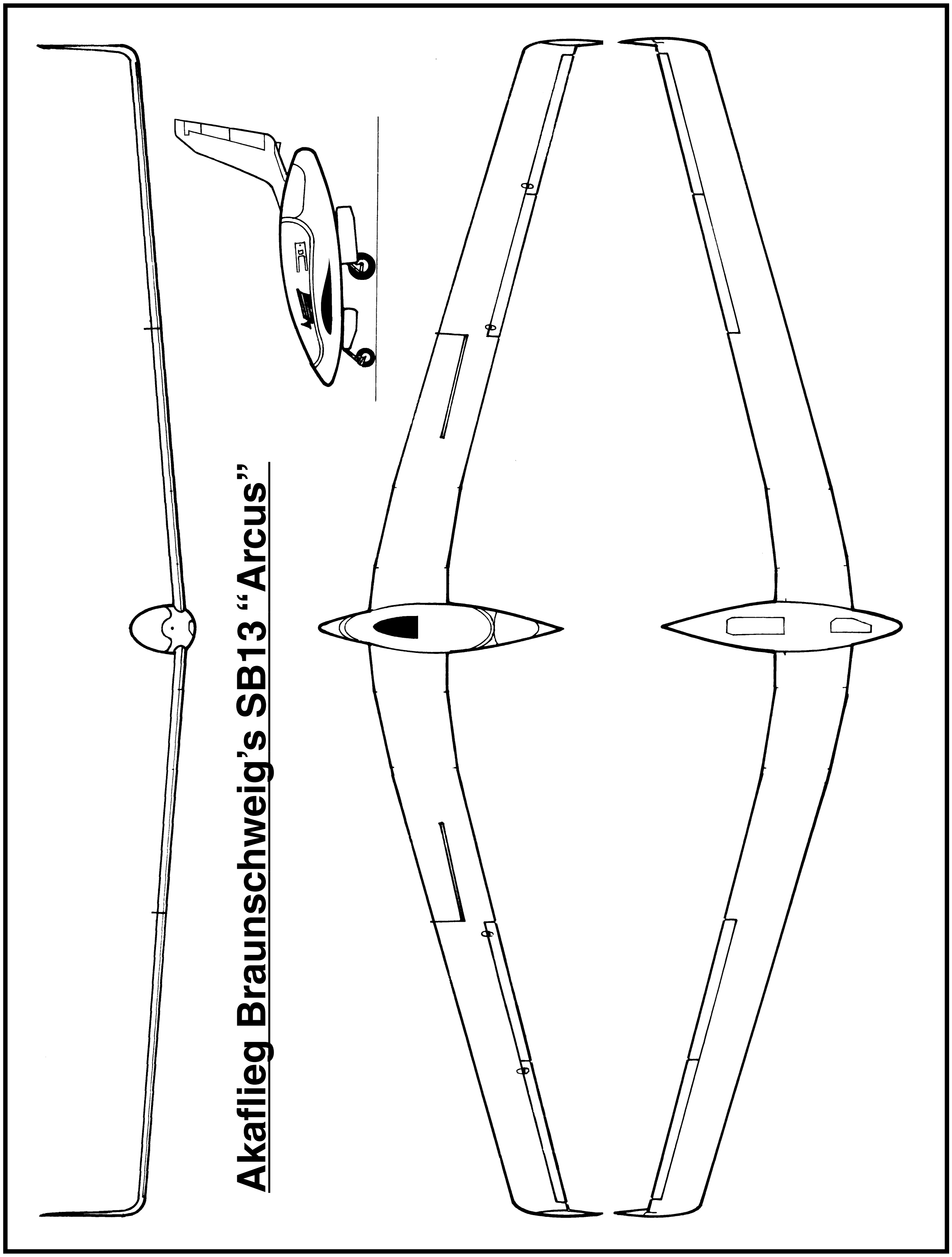
Akaflieg Braunschweig's SB13 "Arcus"
an update

In one of our first columns (*RCSD*, Vol. 5 No. 9, September 1988) we described the then new SB13. This full sized swept wing tailless sailplane, product of the Technical University of Braunschweig, Akaflieg Braunschweig, had flown just six months prior, and specific information about its construction and performance had not yet appeared. Interest in the SB13 has not declined over the intervening years, and there are at least a few modelers, ourselves included, who have expressed an interest in building a replica.

Akaflieg Braunschweig is one of nine institutions in Germany known as Akademische Fliegergruppe (academic flying group), or simply Akaflieg. The history of these groups can be traced back to the years immediately following World War I and the Versailles Treaty. As powered aircraft were forbidden under the Versailles Treaty, but the desire to design, build and fly aircraft remained, the newly founded Akafliegs concentrated on sailplane development. Because of a similar but wider ban on all aircraft development following WWII, it was not until 1951 that these groups could again be active. Since then, however, they have been both active and productive. Table 1 lists just a few of the accomplishments of the Akafliegs. Akaflieg Braunschweig is probably one of the more prolific groups, having designed, constructed and flown several advanced sailplanes, yet it has only about 25 students enrolled at any one time.

The primary goal of the Akafliegs is to synthesize academics, developments in aerodynamics, and new materials to design and build better sailplanes, but a few powered sailplanes and lightplanes have also been produced. Organization centers on the Idaflieg, the Syndicate of German Academic Flying Groups. Guidance, major funding, a number of technical facilities, and much equipment come directly from the DFVLR, the German Aerospace Research Institute. Materials, tools, access to private technical facilities, and additional funding come from the aerospace industry. Students, when not building prototypes, are involved in other activities, as eligibility for flying the group's sailplanes is dependent upon accumulated work hours.

Akaflieg Braunschweig's 1982 decision to build the tailless SB13 was based upon three arguments. First, it was felt recent standard class sailplane performance improvements were due primarily to use of laminar flow airfoils and development of better fuselage aerodynamics. Future performance


Akaflieg Braunschweig’s SB13 “Arcus”

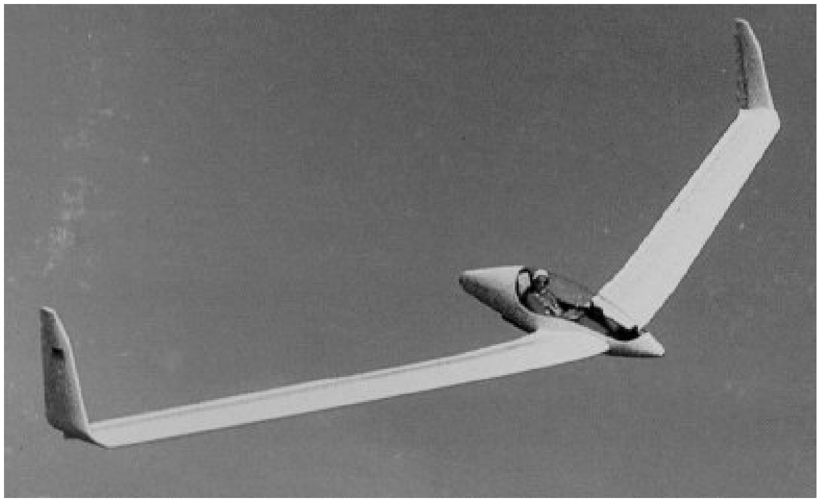
Sailplane	Distinctive Characteristics
fs-24 Phönix	• first sailplane constructed entirely of fiber reinforced plastics
SB10 Schirokko	• first use of carbon fiber in a sailplane • four world records in 1979 • best two place sailplane for over 10 years
fs-29 Teleskop-Flügel	• first and only telescopic wing sailplane
SB11 Antares	• equipped with Wortmann flaps • made entirely of carbon fiber • piloted by Helmut von Reichmann, it won the world championship in 1978, just weeks after its first flight
SB12	• first sailplane with active boundary layer control
Mu28	• fully aerobatic • automatic trailing edge flap • maximum airspeed 250 mph
SB13 Arcus	• first tailless sailplane to be constructed with modern composite technologies • first use of carbon fiber control rods in an aircraft • development of a process for molding a monolithic curved spar
Akaflieg designations: fs = Stuttgart, SB = Braunschweig, Mu = Munchen	

Table 1

improvements using tailed planforms were therefore predicted to be relatively small. Second, building a tailless sailplane would be scientifically interesting, as a competitive tailless sailplane had not been built for three decades. Third, it was felt the tailless planform, due to its smaller number of parts, would be more rapidly built than a conventional design.

The third argument turned out to be completely fallacious, as many of the difficulties which would eventuate had never been addressed before, and solutions to these aerodynamic and structural design problems could not be directly derived from experience with conventional tailed designs.

Sweep back was chosen so the elevator had sufficient leverage, and the wing tip chord was kept relatively large to improve the lift distribution. This large chord allowed sufficient section depth to support vertical fins at the wing



ends. The fins were then designed to cover the entire wing tip, providing sufficient area with reasonable height, and acting as winglets to reduce induced drag. A dihedral angle of four degrees was chosen to provide ground clearance for the wing tips during landing.

The laminar flow airfoil sections for the SB13 had to be designed for good stalling characteristics, high lift, minimal pitching moment, and a resistance to air flow disruption resulting from debris on the leading edge. Modern laminar flow airfoils, fairly easily designed utilizing modern computer software, seemed to be tending toward all of these characteristics, and so designing the new airfoils did not present any major difficulties. The HQ 34N/14.83 was chosen for the wing root, and the HQ 36K/15.12 was chosen for the outboard portions of the wing where the ailerons and elevators are situated. Both of these sections are shown in Figure 1. The HQ 36K/15.12 features a down turned trailing edge. This relieves the otherwise incessant download on the control system caused by the airfoil’s reflexed camber line. Once the HQ 34N/14.83 and HQ 36K/15.12 were shown to be equivalent to other modern laminar flow airfoils in all

Figure 1

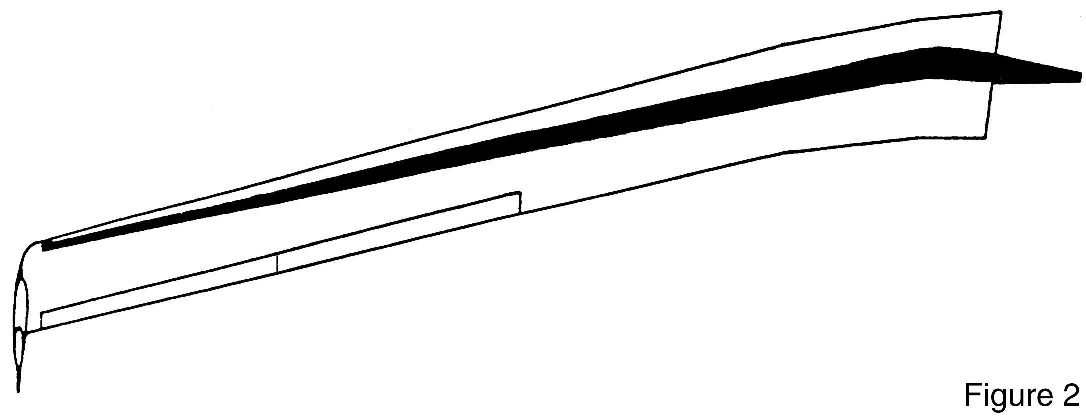


Figure 2

performance dimensions, Akaflieg Braunschweig felt it was possible to build a tailless sailplane with better performance than any existing standard class glider. (A condensed version of the rules for the standard class is provided at the end of this column.)

A 1/3 scale model of the initial design was built and flown, but two problems immediately arose. The model would enter a spin when stalled, then spin in the opposite direction when recovery was attempted, and severe flutter was in evidence even at low speed. While the airfoil chosen for the model was responsible for the stall-spin characteristics, the flutter problem was not so easily identified. It was only after computer modeling by Messerschmitt-Bölkow-Blohm that the sources of the problems were identified and specific changes to the spar structure could be recommended. That structural change involved reducing the sweep angle of the main spar at the wing root. The graceful curve of the inner portion of the SB13 wing was a direct result of integrating the redesigned spar with the chosen airfoils and the overall wing sweep needed for stability.

This was the first time construction of a spar of this type was to be attempted, and Akaflieg Braunschweig was forced to invent a method of creating a one piece complex curved structure of laminated unidirectional rovings and bidirectional fabrics. Inadvertent mishandling which could damage the materials had to be avoided and the entire spar had to be fabricated in less than five hours to assure proper matrix formation. Following fabrication of a portion of one spar as a preliminary exercise, both full length monolithic spars were molded successfully. An overhead view of the SB13's spar system is depicted in Figure 2.

Testing of the completed wing structure included loading it to 13g (7.5g expected load with a safety factor of 1.725). The wing was eventually loaded to 16.5g without failure. Testing concluded, construction of the remaining portions of the primary structure was rapidly completed. The control system, however, which is quite intricate, took longer to construct and install than expected. Carbon fiber rods were used in this application, another first for the aviation industry.

The resulting aircraft was then tested for resonance frequencies to determine the speed at which flutter would occur. Data and computer modeling showed flutter occurring above 270 km/h (168 mph), a speed which is significantly higher than the SB13's 210 km/h (131 mph) maximum.

The first flight of the SB13 took place on 18 March 1988. Aerotow was employed, with a nose attachment point. Launched from a height of 3000 feet, it became the first tailless sailplane to be built with modern advanced composite technologies.

Flight testing showed only one major problem. Flight performance improved as the CG was moved back, but at extreme rearward position the SB13 would easily enter a spin – spins were sometimes induced by turbulence alone. Tuft studies carried out under conditions of higher stability showed cross span flow at the leading edge which precipitated stalling of the outer wing. Flow fences were installed on each wing at the leading edge and in line with the aileron root. This entirely solved the abrupt stall problem and dramatically improved the flying characteristics in all regimes. At last report, there were five pilots rated for the SB13.

The glide ratio of the SB13 is reported to be at least 42:1, with one source reporting 43.5:1. This is an excellent value for a standard class sailplane. Table 2 provides the glide ratio and maximum speed for a number of well known standard class sailplanes. Although its maximum speed is lower than

The SB13, with the SB10 in the background.

Year of First Flight	Builder and Nomenclature	Glide Ratio @ mph	Max. Speed, mph	Min. Sink ft/sec @ mph
(1988)	Akaflieg Braunschweig SB13	43 @ ??	131	1.74 @ ??
(1979)	Akaflieg Aachen FVA-20	35 @ 56	155	1.97 @ 42
(1978)	Grob G-104 Speed Astir II	41 @ 74	168	1.97 @ 47
(1977)	Bölkow Phoebus B3	39 @ 58	124	2.00 @ 51
(1977)	Glaser-Dirks DG-200	42 @ 68	168	1.80 @ 45
(1977)	Schleicher ASW 20	42 @ 60	168	1.97 @ 45
(1976)	ISF Mistral-C	37 @ 58	155	2.17 @ 43
(1976)	Schempp-Hirth Mini-Nimbus HS-7	42 @ 62	155	1.87 @ 50
(1975)	Schleicher ASW 19	38 @ 65	152	2.13 @ 45
(1974)	Grob G-102 Astir CS	38 @ 65	155	1.97 @ 47
(1974)	Glaser-Dirks DG-100	39 @ 65	161	1.94. @ 46
(1969)	Schempp-Hirth Standard Cirrus (Cirrus 75)	36 @ 53	137	1.87 @ 44
(1968)	Schleicher ASW 15B	36 @ 55	137	2.00 @ 48
(1967)	Glasflügel H 301 Libelle	39 @ 59	155	1.80 @ 46
(1938)	DFS Meise	25 @ 42	136	2.20 @ 37

Table 2

most modern standard class ships, its thermaling ability is said to be significantly better than that of conventional tailed sailplanes. Minimum sink is reported to be an extremely low 0.5 m/sec, and stands in contrast to rates of about 0.6 m/sec for tailed ships of its class.

Since a 1/3 scale model of the SB13 has already been constructed using relatively conventional construction techniques, modelers should not be easily dissuaded from constructing a large scale replica of their own. A 4-view of the SB13, based on information and drawings found in various issues of the *TWITT Newsletter* and in *Silent Flight*, is provided in Figure 3; dimensions and other data are listed in Table 3.

Dimension	Magnitude
span	15 meters, 49.2 ft.
wing area	11.6 m^2, 124.8 ft^2
aspect ratio	19.4:1
wing twist, total	-1.5 degrees
dihedral	4 degrees
winglet height	1.25 meters, 4.1 ft.
fuselage length	3.02 meters, 9.91 ft.
empty weight	300 kg, 660 lbs.
control surfaces	aileron and elevator, with mixing, and differential rudders
maximum speed	210 km/h, 131 mph
landing gear	2 wheel tandem, retractable
best glide ratio	43.5 to 1
parachute recovery system	vacuum bagged, ballistic extraction, 20 Kg (44 lbs.), 1.35 ft^3

Table 3

Use of the new EH airfoils is recommended, as these sections have a near zero pitching moment and good lift and stall characteristics. The thickness of the EH 3/12 compares favorably with that of the sections used on the full size SB13 and affords the height needed for a stiff, torsionally rigid spar along with plenty of room for servos and control linkages entirely within the wing structure. Wing construction will pose some challenges, but no insurmountable difficulties. The curve of the wings is really the result of connecting three straight sections, sort of a highly modified Scheumann planform. A torsionally rigid spar reinforced with carbon fiber is a necessity, but otherwise a wing structure using normal “foam core and fiberglass skin” construction methods should work well.

Control hookup should, of course, match the original, with interconnected ailerons and elevators, differential rudder function, and spoilers. (The SB13 control system will be examined in detail in a future column.) Set aside an additional channel for retracting and extending the landing gear.

The SB13 is a truly beautiful machine which very much deserves to be accurately modeled. We'd appreciate hearing from *RCSD* readers who tackle this scale project.

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SB 13 web page: <http://www.tb-bs.de/studenten/akaflieg/SB13.html>

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T.W.I.T.T. Newsletter #4, 10, 21, 23, 26, 29, 36, 57, 83, and 84. Back issues and subscriptions are available from T.W.I.T.T. (The Wing Is The Thing), P.O. Box 20430, El Cajon CA 92021.

Welch, Ann. *The Complete Soaring Guide*. London: A & C Black Ltd., 1986.

BASIC RULES FOR STANDARD CLASS SAILPLANES

1. 15 meter span maximum. Devices for increasing lift, i.e. flaps, are prohibited.

2. Air brakes are mandatory, but they cannot increase lift or improve performance.

3. The landing gear may be either fixed or retractable. The main wheel must be at least 300 mm in diameter and have a width of at least 100 mm.

4. Jettisonable water ballast is permissible.

A Fauvel AV 221/222 at a meet in England. Photo by Eric Marsden.

Kelly McComb's Spar System

Several of our past articles have dealt with flutter problems in swept wings and examined various means of inhibiting that destructive behavior. Kelly McCombs of Utah sent us a rather complete package of materials which details his method of building a very strong box spar using the vacuum bagging process. The package included a small cross-sectional piece of an actual wing built using his system.

A box spar is inherently strong in torsion, but Kelly's technique allows tailoring of the various parts so the assembled spar can withstand specific loads of high intensity. By using various types of fiberglass and carbon fabrics, for example, the spar can be made more rigid in the span-wise direction. The spar can also be made stronger at the wing root than at the tip by adjusting the types of materials and the number of layers used.

The real "secret" of Kelly's spar system is the use of 3M's "77" spray adhesive to hold the fiberglass and/or carbon fiber in place during application of epoxy and the vacuum bagging process. Kelly says it works great. An added benefit is the leading edge is close to being finished right out of the vacuum bag.

Kelly uses polycarbonate as the carrier, rather than Mylar™. He finds the polycarbonate material is available at a lower price than mylar — a 2' by 4' piece costs about $3.50 at any plastics shop. The polycarbonate is optically clear and gives an excellent finish. After coating with Armor-All™ or Rain-X™, this material can be painted so the finished wing is colored. As with mylar, the polycarbonate can be reused if you're careful with it. Kelly cut his carrier so it was just 1/16" short of the leading edge.

Kelly's process is a bit different than what is usually seen, as the box spar core is first cut out of the wing core, then replaced after fiberglass and/or carbon fiber is applied to it as deemed appropriate by the builder. Epoxy needs to flow into the spar area while the wing is under vacuum, but this is not a problem so long as Kelly's directions are followed.

Begin by cutting out the foam core. Note the length of the core will need to be about 1" more than the eventual length of the wing panel. Cut out the foam core as is your usual practice, then cut out the area which will form the box spar. Leave the last 1/2" of each end of the core untouched, as seen in

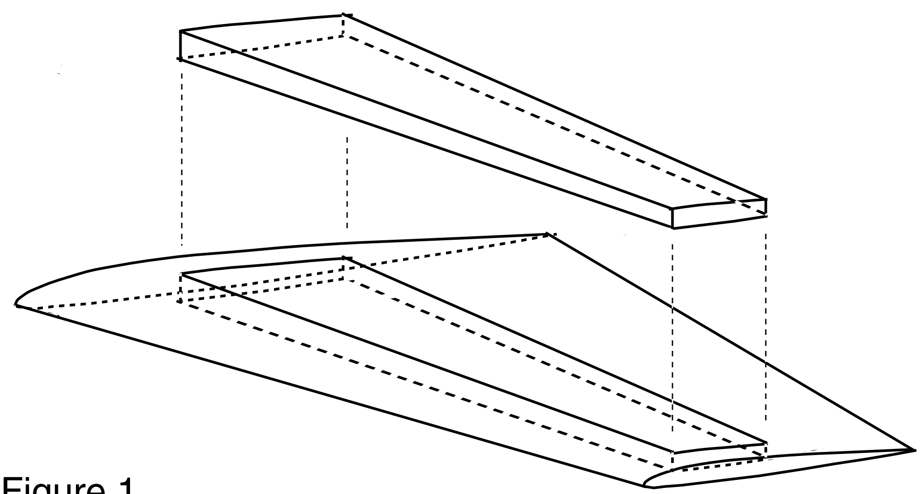


Figure 1

Figure 1. That last 1/2" at each end serves to hold the main part of the core in alignment.

Apply strips of fiberglass to both the front and rear face of the spar. Use 3M "77" spray adhesive in light coats to hold everything together. Don't forget you can make this webbing thicker at the root by putting on more layers. Once finished with this stage, spray the box spar with 3M "77" and wrap a layer of fiberglass around the assembly. Once satisfied with the box spar structure, push it back into the foam core.

Apply the fiberglass skin to the foam core, again using 3M "77." Spar caps of carbon fiber can be laid out on the upper and lower surfaces of the wing directly over the vertical spar webbing and between layers of the fiberglass wing skins. Brush epoxy over the wing surface using a 1½" brush. The polycarbonate, previously sprayed with a layer or two of paint, is then brushed with epoxy. Brushing another coat of epoxy on the core assures there is a sufficient supply of epoxy to the spar area.

Once the polycarbonate is laid out over the fiberglass and epoxy, the vacuum is applied and the entire wing assembly is left to cure.

The resulting structure is very strong, torsionally rigid, and relatively light. For additional information on this type of wing structure, look at the sketch and of the Vari-EZE wing in the September 1991 issue of *RCSD* or in "On the 'Wing... the book."

One additional trick... Kelly has found Kevlar™ thread laced vertically through the foam core before vacuum bagging really helps in preventing the fiberglass skin from peeling away at critical areas of the wing. The thread is not at all noticeable when the wing is completed, but it does become an integral part of the fiberglass skin.

The natural function of the wing is to soar upwards
and carry that which is heavy up to the place
where dwells the race of gods.
More than any other thing that pertains to the body
it partakes of the nature of the divine.

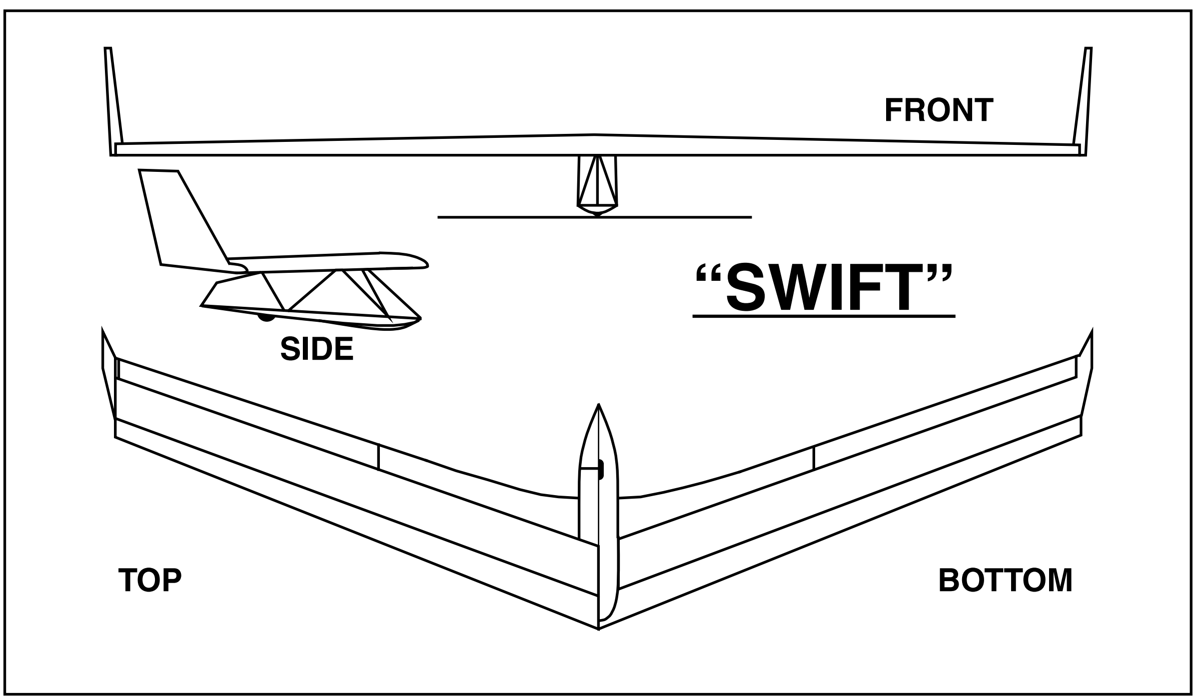
— Plato

Steve Morris and the "SWIFT"

In the early 1980s we took our two Ravens to a large field north of our home for an afternoon of flying. We were just getting unpacked when another car drove up. A young fellow jumped out and said he was going to be flying his helicopter over in the far corner of the field. After checking for frequency conflicts, he set up his helicopter and we continued dragging stuff out of our car. The helicopter was soon cavorting around the sky, and we had one of our Ravens ready for the high start.

We launched the Raven and watched as she climbed out. The helicopter came to a screeching halt in the middle of a maneuver and began a plummet to the ground. Following a rapid but safe landing, the pilot ran to the 'copter and turned everything off. Our Raven was still on the line as he turned to run to where we were standing.

Bubbling with excitement, he exclaimed, "Wow! I can't believe it! Someone else is interested in tailless sailplanes! This is fantastic!" Over the next hour or so, the young helicopter pilot flew the Ravens, and we discussed tailless sailplanes at some length.



This was our introduction to Steve Morris. Over the next few months, we learned that Steve worked for the Boeing Company in their missile division, but that his true loves were low Reynolds number aerodynamics and unconventional planforms. He had a computer system which he portrayed as being "more computing power than man was meant to have," and had already experimented with large swept wing planforms. At the time of our meeting, Steve was working on a smaller, lighter, computer-designed swept wing planform, doing quite a bit of hang gliding, and contemplating returning to Stanford University for his doctorate degree.

Dr. Stephen Morris' name is now "in the news" following release of the "SWIFT," an FAI Class II hang glider which he designed with Prof. Ilan Kroo of Stanford University. There are several characteristics which make the "SWIFT" unique. It is a tailless rigid wing glider with excellent performance. It is easily carried on the top of a car, can be assembled in a matter of minutes by a single person, and is capable of flying hundreds of miles with a high degree of comfort for the pilot.

The "SWIFT" (Swept Wing with Inboard Flap for Trim) provides sailplane performance with hang glider convenience. It is usually foot launched from the slope, but can also be towed to altitude. True aerodynamic control surfaces, elevons and flaps, provide positive control at all flight speeds. Elevons are operated by a single side mounted control stick — just like modern jet fighters. The flaps, which provide a speed range of from below 20 to over 70 m.p.h., are controlled by a mechanism on the opposite side of the cockpit. With a glide ratio of 25:1, the "SWIFT" has a tremendous potential range. Foot landings are not at all traumatic, due to the low stall speed of the "SWIFT," and a small fuselage mounted wheel makes for effortless landings on smooth surfaces.

The "SWIFT" has a number of positive attributes which make it a good scale subject. The relatively short wing span is conducive to both 1/4 or 1/3 scale; just under 3 meters and just under 4 meters, respectively. The root airfoil seems to have a cusp on the upper rear surface — something like a Liebeck section. This could be easily duplicated with one of the reflexed airfoils designed for model use. The wing is deep enough for all electronics to be

totally enclosed, although batteries and receiver could be placed in a hollow “pilot.”

The simplicity of hang glider instrumentation, typically just an air speed indicator and variometer, is a bonus for those who appreciate details but dislike spending inordinate amounts of time with extensive detailing. The pilot is enclosed in a transparent fairing, and this provides some additional challenges to the modeler.

The “SWIFT” has been featured on several television programs and in a number of magazine articles, and a videotape is available from the manufacturer, Bright Star Gliders. The Bright Star Gliders tape includes information on fabrication techniques and car top transportation, in addition to some beautiful in-flight footage.

The “SWIFT” is constructed of Kevlar™ fabric and carbon fiber over a solid foam core, just as our modern models. Building a large scale model of the “SWIFT” would therefore not pose many problems, but would certainly amount to an impressive accomplishment.

The “SWIFT” videotape is available in VHS NTSC format (U.S.) for US$24, and in VHS PAL format (Europe, Australia, etc.) for US$29. Contact: Bright Star Gliders, 48 Barham Avenue, Santa Rosa CA 95407, (707) 576-7627

Photographs used in this article came from the Hang Gliding WWW Server Home Page: <http://cougar.stanford.edu:7878/HGMPSHomePage.html>.

Classification	FAI Class II hang glider
Wingspan	39 ft. (11.89 m)
Tip chord	3.03 ft.
Taper ratio	0.75
Wing area	135 ft.^{2} (12.54 m^2)
Aspect ratio	11.5:1
Weight	115 lbs. (50 kg) without ‘chute* 135 lbs. (62 kg) with ‘chute*
Rated load	+6 g to -4 g
Flap span	8.58 ft.
Flap chord	25%
c/4 sweep angle	20 degrees
Wing twist	8 degrees
CG location	4 ft. back from apex of leading edge
L/D	24:1 maximum, with pilot fairing 15:1 at 60 m.p.h. (97 kph) 20:1 maximum without pilot fairing
Vne	75 m.p.h. (120 kph)
Aerodynamic concepts by Prof. Ilan Kroo and Dr. Stephen Morris	
Design, structure, and development by Brian Robbins, Eric Beckman, and team pilot Brian Porter	

* Second Chantz, Inc. “Pocket Rocket” HG-350 ballistic parachute system

Winglets vs. a Single Central Fin

In looking over some photographs and contest descriptions in recent issues of *Silent Flight* and *Flug- und Modelltechnik*, we suddenly came upon some information which may be of use to designers of swept wing tailless sailplanes.

We noticed nearly all swept 'wings in European competition fall into one of two categories. They have either two fins, one at each wing tip, or a single central fin mounted on a boom. In the descriptions of the contest winners, those with two fins were characterized as the better thermal performers, while those with a single fin were said to track better in straight line flight.

There are a couple of logical reasons for this:

- Fin area mounted at the end of the wing acts as a winglet, increasing the effective span and preventing formation of a large vortex from the wing tip. This increases the potential C_{Lmax} — just what's needed during thermaling.
- A single central fin provides more directional stability because its surface area remains further behind the CG during yaw, thus providing greater leverage in a more consistent manner. It has no way of affecting the air flow over the wing tips, however.

If you are designing a thermal duration or F3J 'ship, place the vertical fin area at the wing tips. If you are designing a 'ship which will be flying at higher speeds and in straight lines, a single central fin is probably best.

As two of three F3B tasks involve primarily straight line flight and only one task involves thermal duration, it seems a single central fin may be best for that event. But what about F3F? In this event, high speed flight and good tracking are very important, so a single central fin looks like a good choice. High g turns with maximum ballast, however, require sustained C_{Lmax}, and this task is better suited to winglet equipped 'wings.

Penumbra.3 at 60 Acres. Photo courtesy of Bruce Abell.

Slots for Swept 'Wings?

There is little doubt the design of swept wings presents a number of challenges. Perhaps one of the greatest challenges is directly related to sweep itself. In previous columns we've discussed the deleterious effects of cross-span flow, and this month we'll do it again.

Cross-span flow occurs any time the wing is swept. For wings which are swept back, the flow tends towards the wing tip, while the flow on swept forward wings tends toward the fuselage. Some designs can take advantage of cross-span flow, as the NASA X-29. Our models, however, do not usually react to cross-span flow in positive ways.

If the air flow runs parallel to the chord line, laminar separation can be controlled either during the airfoil design process or by strategically located "trip strips." There is no way to know, however, where the boundary layer will break away under cross-span flow conditions, but for swept back wings the end panels of the wing will surely be affected. Since the pitch and roll control surfaces are in this area, positive control will be problematic. Additionally, C_{Lmax} will be reduced and large amounts of drag will be created.

The classic method of dealing with cross-span flow is to install a fence parallel to the local wing chord, extending over the leading edge and back well past the quarter chord point. The idea is to create a barrier to the flow, much like the action of a tip plate at the end of a wing. One fence on each wing proved very effective on Akaflieg Braunschweig's SB13 "Arcus." The major problem with fences is their inherent high drag — a sum of their parasitic drag and interfence drag, plus their induced drag, a product of their being at an angle to the oncoming air flow.

We recently received an interesting letter from Mark Nankivil in which he explained a rather unique leading edge slot which he feels will be as effective as a fence and yet present far less drag. While Mark borrowed the idea from high speed aircraft, it should certainly be adaptable to model use.

"I want to make a case for flying wings in the 10 cell F5B event and also in Speed 400 and 7 cell pylon racing. As you probably know, there has been some good success in Europe with wings in electric pylon racing... the Aussie *Electric Flight Newsletter* shows success Down Under, too.

"In flying the F5B event, the one challenge is to minimize the turning radius during the distance portion of the task. In 'Faszination Nurflügel' the F3E (now F5B) model by Urs Leodolter was shown and discussed in one chapter. As I recall, straight line speed was not the problem, it was turning radius and the time wasted in making the turns at each base on the distance task. The flying wing would essentially high speed stall if wrapped into too tight of a turn. My thoughts on this are to eliminate the flow separation on the upper surface in tight turns by using a vortex to keep the flow attached in the tight turns.

"As I see it, two ways of achieving this are to go with a fixed canard or leading edge slots...

"Nothing original on my part, I just looked at full size delta wing and swept wing practices on the better operational fighters. Deltas (F-102, F-106, Mirage, etc.) have a high instantaneous turn rate but immediately run into high drag growth which inhibits sustained turn rate. The Israelis got around most of this problem by going to a fixed canard on their Kfir that improved the sustained turn rate dramatically. I think this will work in model form. However, the angle of attack of the canard would be difficult to optimize and drag gain elsewhere in the flight envelope would be likely without a lot of effort being spent on canard location and its angle of attack.

"The more enticing method would be to go with leading edge slots as used on the Sukhoi Su-15 Flagon or Saab Viggen. This lot is a vertical cut in the leading edge that forms a vortex over the top of the wing when the angle of attack increases. When the nose is down and the model is going for speed, the slot has very low drag, much better than a fence, and should have minimal effect on airframe drag. It also has the advantage that it can be placed where it is needed along the span of the wing...

"The slots will be tested later this Spring on a two meter EH flying wing for use in the 10 cell F5B class. More on this as it comes to pass..."

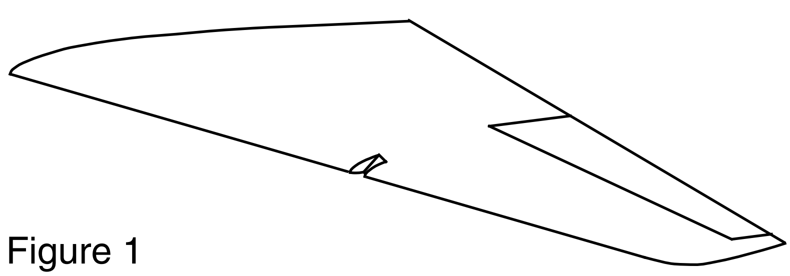


Figure 1

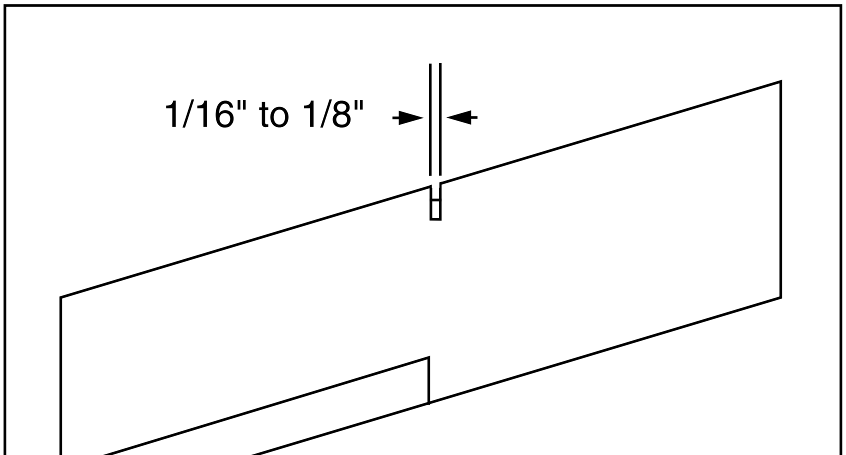


Figure 2

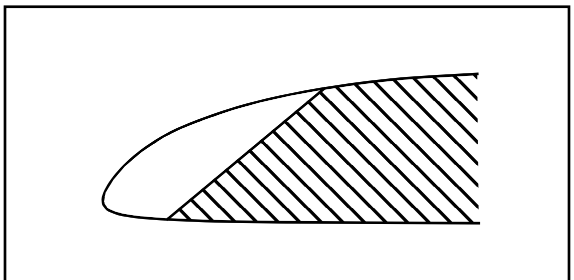
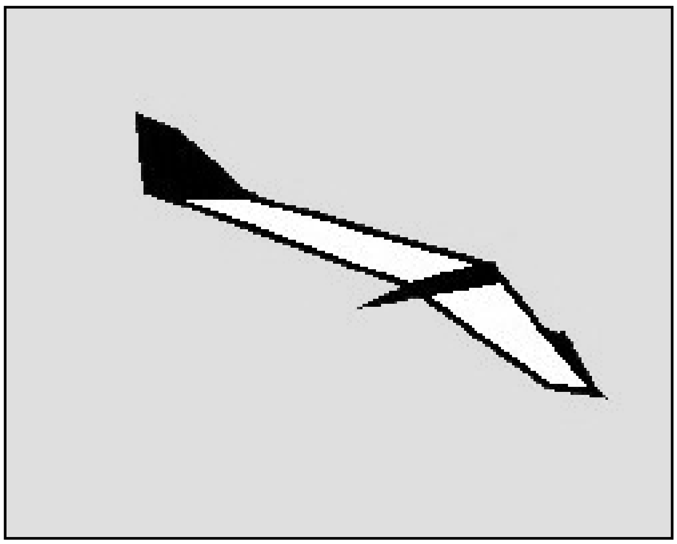


Figure 3

The slot, shown in various views in Figures 1, 2, and 3, creates a small vortex which turbulates the flow in the region behind the slot. This vortex mixes the stagnant boundary layer with air molecules having higher energy. The action of the slot is similar to that of a variable orientation trip strip. It will not stop the cross-span flow, but will inhibit the laminar separation which can be so detrimental to consistent pitch and roll control. There should be an increase in effectiveness as the C_L increases.

We encourage Mark to experiment with leading edge slots and share his findings with *RC Soaring Digest* readers.

Mark concluded his letter, "If I can solve the turn rate/drag increase problem, then I think there can be a quantum leap in competitiveness for flying wings in F5B and F3B. I'm excited about the possibilities!"



Andrew MacDonald's web page icon.
<http://www.cs.net.au/~andy/>

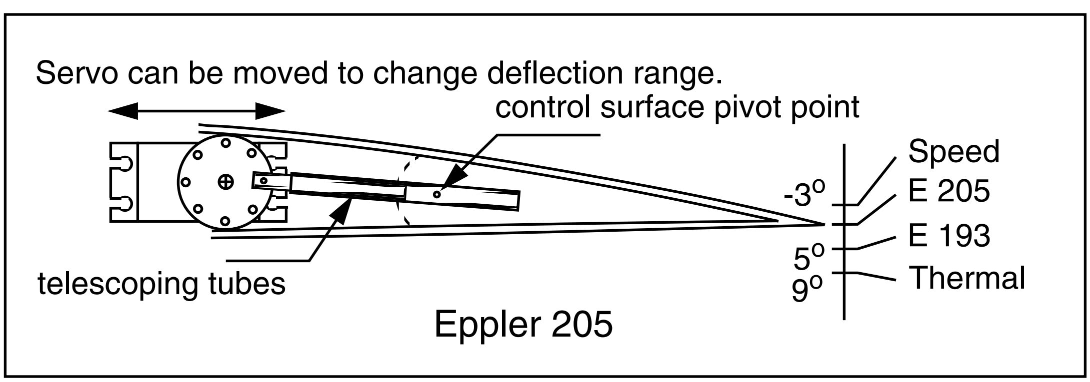
A Novel Control System Mechanism

An unconventional model from Holland provides an idea for enthusiasts of tailless planforms...

We often receive inquiries about trimmable control surfaces. In addition to the standard aileron and elevator or elevon complement, the designer may wish to have a "trim tab," as this can be quite handy when trimming a tailless sailplane for best performance within a specific flight regime. Until this idea appeared in DELTA, however, every mechanical system we had seen had two problems; drag from various mechanical components protruding into the airstream, and "system slop."

In order for the servo to transmit its relatively large forces to the control surface for appropriate deflection, some sort of mechanism must be designed and built which will provide the needed control surface deflection range and an appropriate mechanical advantage. The most obvious way of accomplishing this is to put a rather large arm on the control surface, and attach a smaller than usual servo wheel to the servo. But a long control horn is anti-aesthetic, produces a large amount of drag, and disrupts the local airflow over the control surface. We have found such control systems also lack rigidity.

The control system sketched here, however, has some real advantages. There is nothing protruding from the wing or control surface, so it is aerodynamically clean, and there is a minimum of slop in the physical system. Additionally, a standard servo wheel can usually be used. This system consists of a set of telescoping tubes which are attached at one end to the control surface and at the other to the servo wheel.



The diagram shows the component layout used within the wings of *Onnozel*, a "noseless" V-tailed sailplane designed for F3B. As you can see, the range of deflection for camber changing is just 12^o — three degrees up and nine degrees down — but the total range of deflection is greater. The control surface can be moved in very small increments while being held rigidly in position at all times.

Readers implementing this control system should begin by either drawing the system geometry on paper or by building a mock-up which allows adjustment of servo position. Less control surface travel, and finer adjustment, can be obtained by moving the servo further away from the control surface pivot point, while more travel can be realized by moving the servo closer. Since the entire mechanism must fit inside the local internal height of the wing, a bit of experimentation is certainly in order.

We would very much appreciate hearing from any readers who utilize this idea in a tailless sailplane.

Four Basic Concepts

Part 1

An aerodyne is defined as any heavier-than-air aircraft which derives lift from motion. The history of aviation is filled with a nearly infinite number of aerodyne planforms, each formulated to achieve the designer's goals.

We've described a multitude of tailless designs over the past five years — from swept back, through "plank," to swept forward planforms — and in the process have examined airfoils, twist formulae, and the effects of sweep and twist on both stability and performance.

Longitudinal stability is probably the foremost concern in the designer's mind as a tailless planform takes shape. This is because successful tailless aircraft are the result of a careful balance of center of gravity, overall pitching moment, and wing twist.

Most designers find it helpful to have some basic logical and consistent "rules of thumb" to rely on during the design process. This series of articles will endeavor to examine and explain four fundamental design rules so they are easily remembered and thus be an inherent part of the tailless designer's thought processes.

We'll begin with a brief outline of the four important concepts to be considered during the design process: (1) center of gravity, (2) pitching moment, (3) sweep angle, and (4) design lift coefficient.

The following points apply to tailless planforms. For simplicity, Figures 1, 2 and 4 show only an airfoil section.

(1) Center of Gravity

Stability is dependent upon the location of the center of gravity — the more forward the center of gravity, the more stable the aircraft. The term stability factor, or static margin, denotes the distance between the center of gravity and the aerodynamic center. The aerodynamic center lies at 25% of the mean (average) aerodynamic chord. Stability factor, or static margin, is defined in terms of percent of mean (average) chord as well. A stability factor of 0.035, for example, places the center of gravity at $0.215\bar{c}$; that is, $3.5\%\bar{c}$ ahead of the aerodynamic center which lies at 25%.

$$0.25 - 0.035 = 0.215$$

If the center of gravity is at the neutral point (aerodynamic center), the stability factor is zero, and the aircraft will not recover from a stall but will instead descend like a parachute, or like it is dethermalized. The static margin provides the restoring moment needed to bring the stalled wing out of the stall. In normal flight, therefore, with a positive static margin, the nose of the aerodyne is being constantly pushed down because the center of gravity is ahead of the aerodynamic center. For controlled flight there must be an opposing force, otherwise the airfoil will be rotated nose down. See Figure 1.

While the force pushing the nose down is independent of air speed, the opposing aerodynamic force is directly related to air speed. Thus, the nose drops as air speed decreases and rises as air speed increases.

The more forward the center of gravity, the more stable the planform. (This is true even if the center of gravity is behind the aerodynamic center. In this case, moving the center of gravity forward increases the aerodyne's stability, although the aerodyne itself is still unstable. As a general rule, so long as the planform is not changed, more twist will be needed as the center of gravity is moved forward.

(2) Pitching Moment

If the wing utilizes a conventional airfoil it tends to rotate nose down during flight because of airfoil section camber as depicted in Figure 2. This will continue into a tumbling action. For controlled flight there must be a counteracting force.

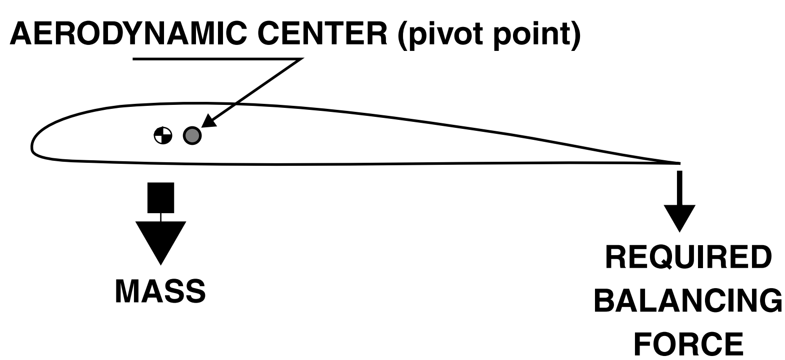


FIGURE 1

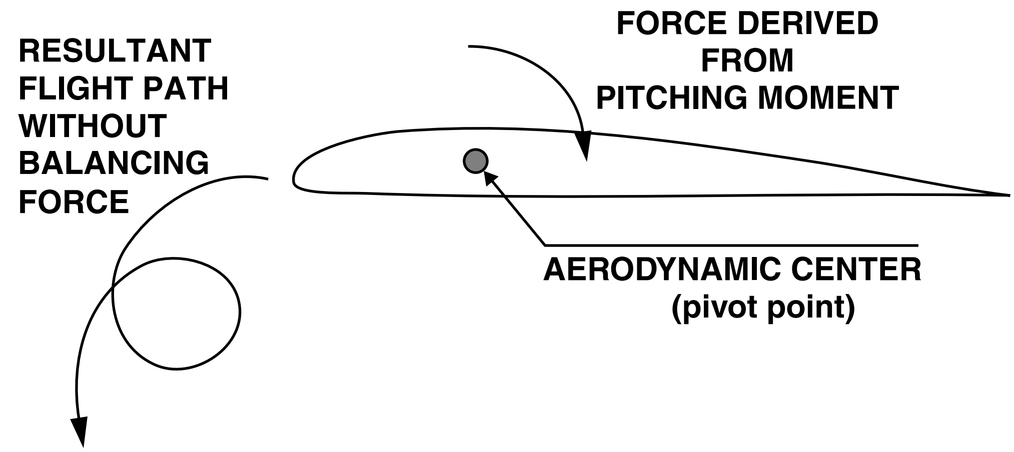


FIGURE 2

Conventional high lift sections usually have strong negative pitching moments. If one of these high lift section is used at the root, a strong aerodynamic force must be produced by the wing tip to counteract the pitching moment of the root section. This is accomplished by increasing wing twist or by changing the wing tip airfoil. Since both the wing root and the wing tip are traveling at the same speed, all of the generated aerodynamic forces are always directly proportional to each other.

(3) Sweep Angle

If the stability factor (static margin) remains constant, increased sweep reduces the required twist. This is because a larger sweep angle places the wing tip further away from the aerodynamic center, providing a larger moment arm. A couple of things to keep in mind, however...

First, rearward sweep is notorious for making winch launching difficult. This is because any yaw produces a powerful rolling force at high angles of attack. Making a small cardboard model of a swept wing planform will assist in understanding how this happens. Simply hold the cutout in front of you, viewing it as if you are standing at the turnaround. Hold the model at a moderate pitch so you are looking at the bottom of the wing. Then rotate the wing in the yaw axis. You will see the forward wing project a relatively larger lifting surface than the retreating wing. This larger lifting surface induces a strong roll moment which cannot be easily overcome by control surface movement. Several designers have gone to zero dihedral to control this yaw-roll problem, while others have utilized anhedral.

Second, increased forward sweep requires a larger fin area for directional (yaw) stability. This is the result of sweep forward being a destabilizing factor. To visualize this, take the cardboard outline used in the previous example and view it from above. Now imagine the wing, with the wing tips forward, yawing slightly. Notice the retreating wing increases in effective span while the advancing wing decreases in effective span. In the case of a moderate forward sweep angle, the drag differential is substantial, and only a large fin can keep the wing in a relatively straight flight path.

Additionally, the retreating wing will produce more lift, inducing a rolling moment opposite to the yaw. Dihedral can at least partially overcome this effect by producing an oppositional force, just as when a conventional tailed sailplane with dihedral but lacking ailerons enters a rudder induced turn.

(4) Design Lift Coefficient

Wing twist must additionally be adjusted to hold the entire wing at the angle of attack required to attain the desired C_L. The angle of attack must increase to achieve a larger design C_L, and increased wing twist is required to hold the entire wing at the proper angle of attack.

It should be noted that large amounts of twist are detrimental to performance due to increased drag. Wing twist should be used to obtain the $C_{Lcruise}$, not C_{Lmax} or $C_{Lthermal}$. High and low flight speeds are achieved through control surface trim. This results in the lowest overall trim drag.

In condensed form, here are the four basic rules which must be kept in mind during the design process:

(1) increased stability (a more forward CG) requires more twist
(2) a larger C_{mroot} requires more twist
(3) decreased sweep angle requires more twist
(4) a larger design C_L requires more twist

Dr. Walter Panknin presented a set of equations at the 1989 MARCS Symposium which covers both the location of the center of gravity and the required wing twist for any tailless planform.

Note the four basic rules regarding center of gravity, pitching moment, sweep angle, and design lift coefficient outlined previously are all included in Dr. Panknin’s formula within Equation 2. This equation also takes into account taper ratio and aspect ratio, but we will not be discussing these two variables here.

$$\alpha_{geo} = \alpha_{total} - (\alpha_{l0root} - \alpha_{l0tip}) \qquad \text{Equation 1}$$

where;

α_{geo} = geometric twist angle, used for construction
α_{l0root} = zero lift angle, root
α_{l0tip} = zero lift angle, tip

and

$$\alpha_{total} = \frac{(K_1 * C_{mr} + K_2 * C_{mt}) - C_L * sf}{1.4 \cdot 10^{-5} * A^{1.43} * \beta} \qquad \text{Equation 2}$$

where;

$K_1 = 1/4 * (3 + 2t + t^2)/(1 + t + t^2)$
t = taper ratio, c_r/c_t
c_r = chord, root
c_t = chord, tip
C_{mr} = moment coefficient, root
$K_2 = 1 - K_1$
C_{mt} = moment coefficient, tip
C_L = overall coefficient of lift with neutral trim
sf = stability factor (static margin)
A = aspect ratio, $b/\bar{c}$
b = wingspan
$\bar{c}$ = average chord; (cr + ct)/2
β = sweepback angle of 1/4 chord line;
+ for sweep back, - for sweep forward

This formula has proven to be very accurate. Other than the dimensions of your creation, you need only know the zero lift angle and moment coefficient of the root and tip airfoil sections you will be using. Computer programs which utilize Dr. Panknin's formula have been available for some time. Once the necessary information is input, the computer will provide all of the additional data you need to build a longitudinally stable tailless sailplane. The necessary computations can also be accomplished on a scientific calculator.

Despite basic knowledge of model aircraft design and very good mathematical formulae, however, it remains difficult for the modeler to visualize the complex relationships between center of gravity, moment coefficients, twist and sweep, and mentally formulate an effective tailless planform for a specific task.

In response, Bill Kubiak, our Minnesota friend, suggested we attempt to integrate the basic trends into graphical form. He recommended focusing on the required twist angle by maintaining a "generic" design with predefined dimensions which would remain constant. Each of a series of graphs would then depict a specific root and tip airfoil combination. With sweep angle being the only variable within each graph, readers would be able to see the relationships between planform and necessary twist in a pictorial fashion which would be easily comprehended and easily remembered.

Following Bill's recommendation, we'll begin by defining those dimensions which remain constant. See Table 1 for this information. It should be noted that the chosen design C_L is relatively high. This was done for graphical purposes only. In practice, the design C_L would be significantly lower.

PARAMETER	DIMENSION
span, b	100"
semispan, b/2	50"
root chord, cr	12"
tip chord, ct	8"
average chord, $\bar{c}$	10"
taper ratio, t	8/12 = 0.67
stability factor, sf, or static margin, SM	0.035
design lift coefficient, C_L	0.6
leading edge sweep	variable, in increments of five degrees, from -20 degrees to + 20 degrees
quarter chord line sweep	variable, from - 21 degrees to +18.98 degrees

Table 1

Figure 3 shows the nine planforms used to generate all of the graphical data included here.

Since this wing is tapered, the quarter chord line does not lie parallel to the leading edge. While it is easier for most people to relate to the leading edge angle, Dr. Panknin's formula uses the angle of the quarter chord line. Table 2 shows the relationship between these two variables. As you can see, the quarter chord angle is always about one degree forward of the leading edge angle.

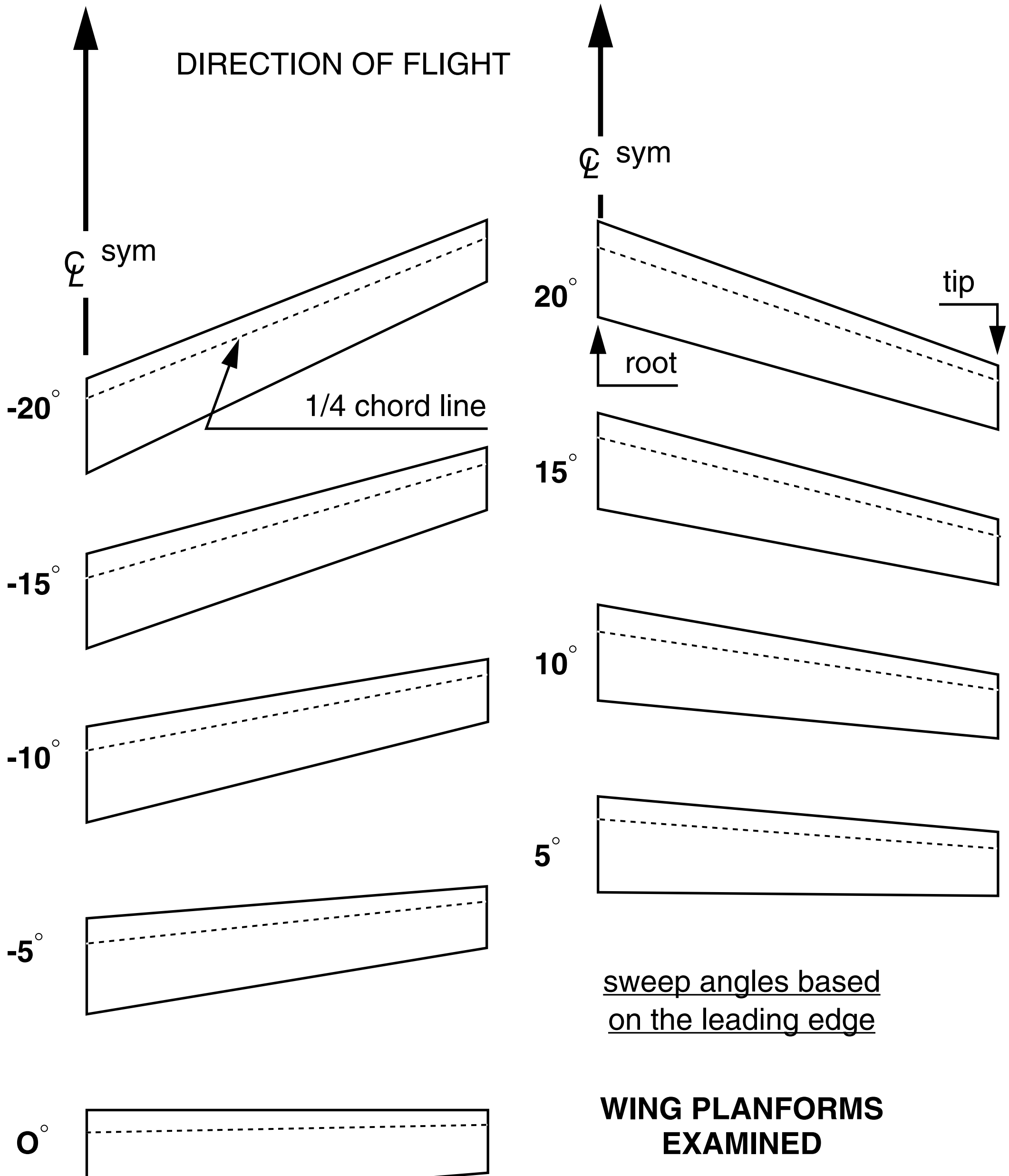

DIRECTION OF FLIGHT
℄ sym
℄ sym
-20°
1/4 chord line
-15°
-10°
-5°
O°
20°
tip
root
15°
10°
5°
sweep angles based
on the leading edge
WING PLANFORMS
EXAMINED

FIGURE 3

The graphs, which will begin in next month’s installment, are based on the leading edge angle. We did this so designs like Jim Marske’s Pioneer planform. with its straight leading edge, could be easily evaluated. If you follow the examples by computing the Panknin equations you’ll need to use the quarter chord line angle from Table 2.

LE	-20	-15	-10	-5	0	5	10	15	20
1/4 chord	-21.00	-16.06	-11.11	-6.13	-1.15	3.86	8.88	13.93	18.98

Table 2

In Part 2 we will begin our graphical examination of the effects of sweep angle and chosen airfoils (See Table 3) on wing twist.

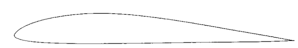
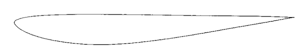
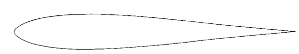
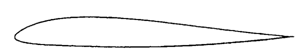
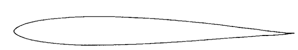
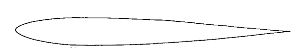
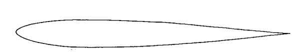
REF	DESIGNATION	C_m	a_{l0}	SECTION PROFILE
1	E 205	-0.046	-2.37	
2	E 205.inv	+0.046	+2.37	
3	Symmetrical	0.000	0.00	
4	EH 2/10	+0.00165	-0.74	
5	E 228	+0.0143	+0.34	
6	E 230.Eppler/MTB 1/2	+0.053	+1.73	
7	E 230.Panknin	+0.025	+1.73	

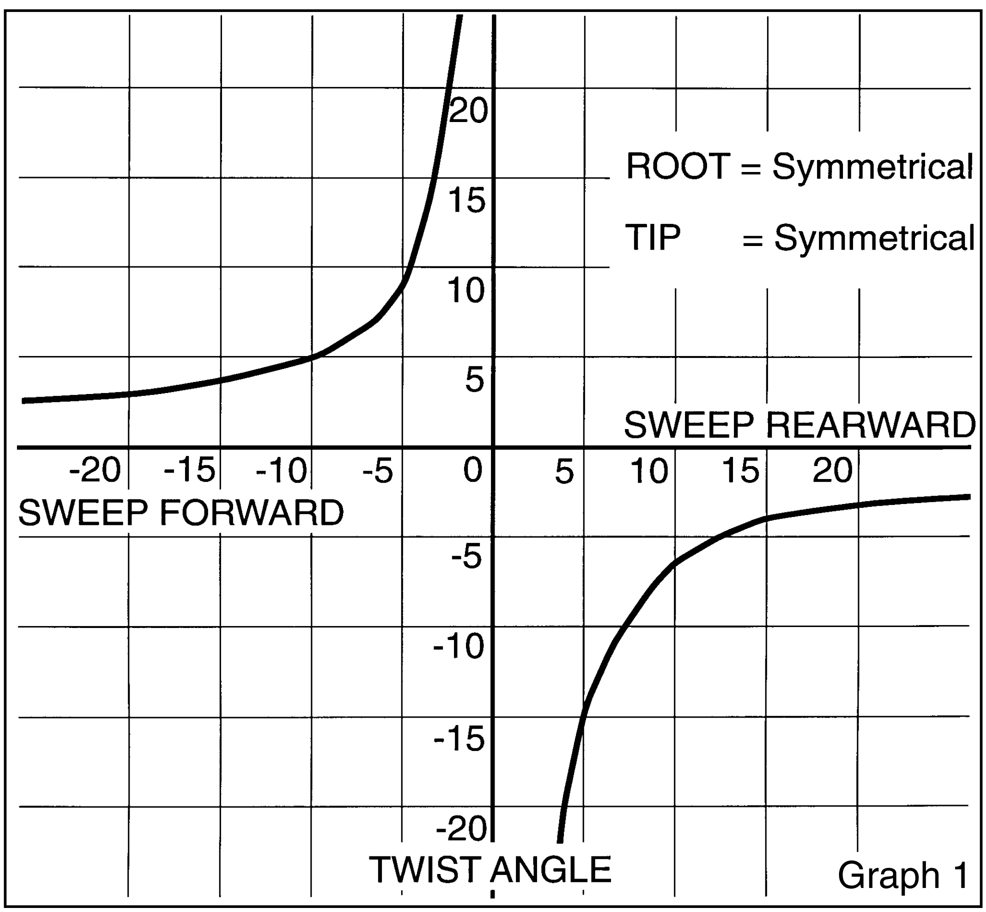
Table 3

Part 2

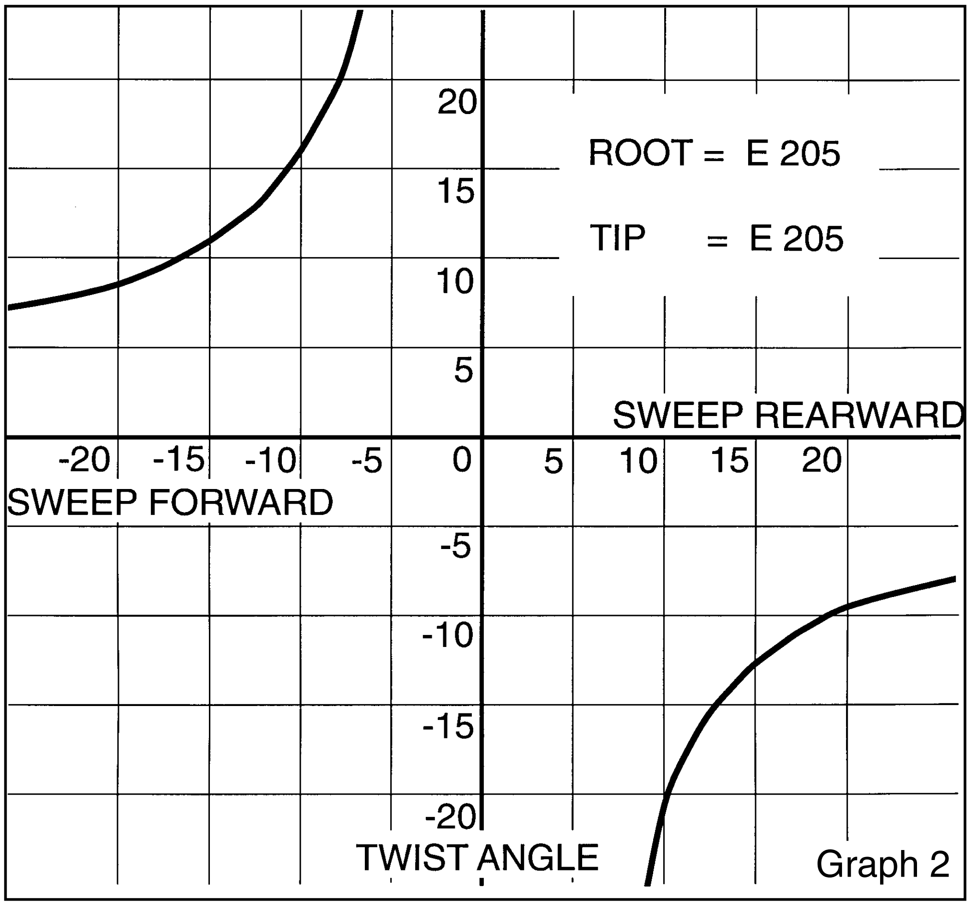
We begin our examination of the effects of specific airfoils and sweep angles on the wing twist needed for a predefined amount of stability and predetermined design C_L. For all of the cases examined here, the static margin (stability factor, sf) is 0.035 and the design C_L is 0.6, a value larger than would likely be used in practice.

Bill Kubiak, instigator of this exercise, was specifically interested in the effects of sweep on twist when the airfoil used is a flat-bottomed section, but as a reference point we will first look at using a symmetrical section. Graph 1 depicts the case where both the root and tip airfoil are symmetrical. In this case the specific symmetrical airfoil used is unimportant, as both the pitching moment and zero lift angle of any symmetrical section are equal to zero. (Symmetrical section: $C_m = 0.0$, $\alpha_{l0} = 0.0$)

Hans Jürgen Unverferth used a symmetrical Quabeck section for his "Just in Time," a high performance swept wing design. The major problem with using symmetrical sections on swept tailless designs has always been their relative



Graph 1



inability to provide large amounts of lift. Until recently, this shortfall was also true of non-symmetrical sections with very low pitching moments. This situation is changing, however, and there are now very low pitching moment sections easily capable of C_l = 1.0 and more. The EH series of airfoils provides several excellent examples of the state of the art and will be discussed later.

Turning to the specific case of a flat bottomed section, we chose the Eppler 205 for both the root and tip sections. (E 205: C_m = -0.046, α_{l0} = -2.37) The results are shown in Graph 2.

There are a few things to be learned here:

- For equal angles of forward and rearward sweep, twist angles are of nearly identical magnitude. In fact, if Graph 1 was based on the 1/4 chord line instead of the leading edge, the magnitudes would be exactly equal for equivalent sweep angles. This is due to the root and tip sections having identical zero lift angles. As the zero lift angles become more dissimilar, differences in twist magnitudes become larger.

- As the sweep angle approaches zero degrees the twist angle approaches a truly unmanageable value. Since the twist angle is extremely large as the sweep angle becomes less than 20 degrees, we are driven to find another method of obtaining needed stability when the sweep angle is less than this value. We'll focus on this point later.

- The twist angle decreases as sweep angle increases, but the twist angle never reaches zero degrees. Additionally, the twist angle is large even when the sweep angle is over 20 degrees. Such large sweep angles make winch launches extremely difficult, as we mentioned previously, and cross-span flow becomes a major problem during certain flight regimes. With rearward sweep the tip section is at a severe negative angle. This may lead to stalling of the lower surface under some conditions.

- In the case of sweep back, the wing tip must provide a down force which can both overcome the pitching moment of the root section and hold the root section at a positive angle of attack to achieve the design C_L. But the wing tip in this case has a negative pitching moment, so it contributes, along with the wing root, to rotating the wing forward and downward. This is the reason such a very large twist angle is needed when both the root and tip utilize the E 205 section.

- The negative pitching moment of the wing tip is also a detriment when the wing is swept forward.

The most obvious difficulty in using the E 205 section for both the root and tip is the large amount of wing twist required for wings with sweep back. This problem can be minimized by using a tip section having a positive pitching moment and which is capable of providing significantly more negative lift. A positive pitching moment, combined with an ability to produce a large amount of negative lift provides the potent downforce required by the chosen root section.

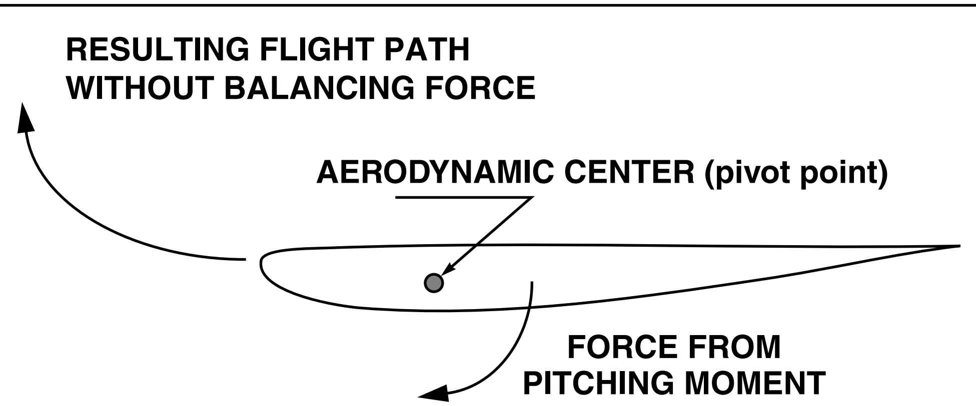
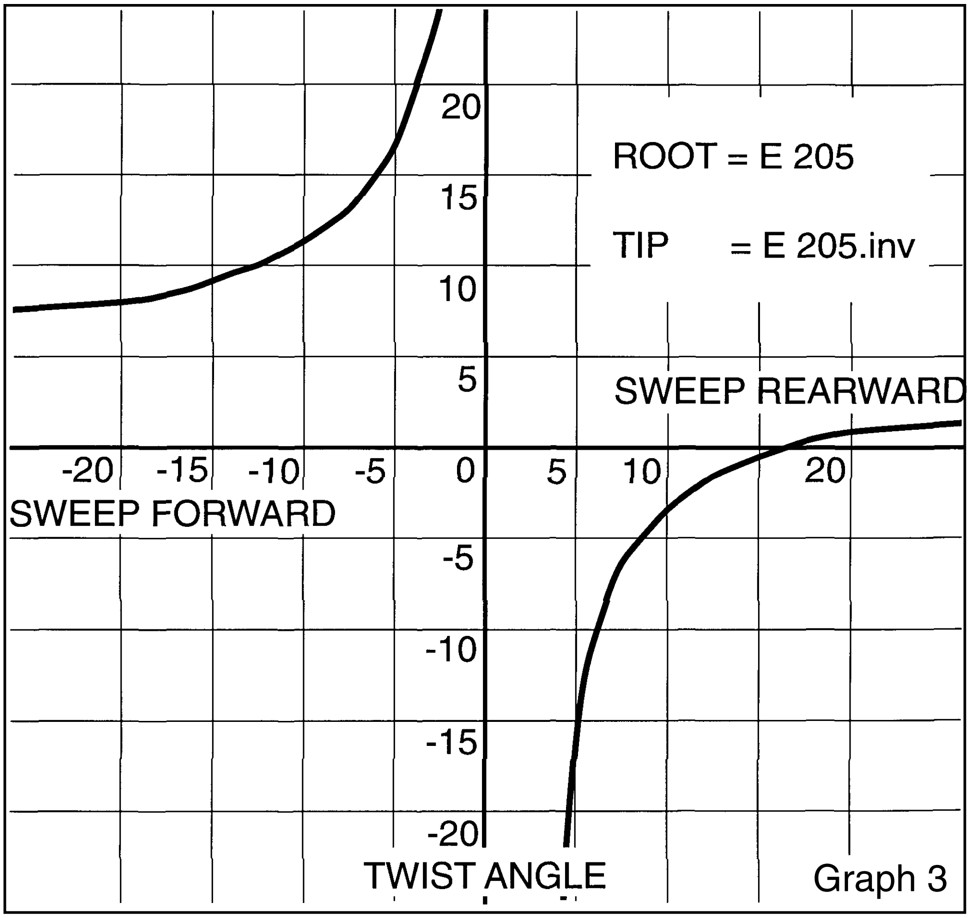


Figure 4



All of this can be accomplished by inverting the E 205 tip section. The pitching moment of the inverted section is positive and this contributes to stability and assists in holding the wing root at the proper angle of attack. Additionally, the airfoil is now capable of producing very large amounts of downward lift because the camber line is oriented appropriately. (E 205.inv: $C_m = +0.046$, $\alpha_{l0} = +2.37$) See Figure 4.

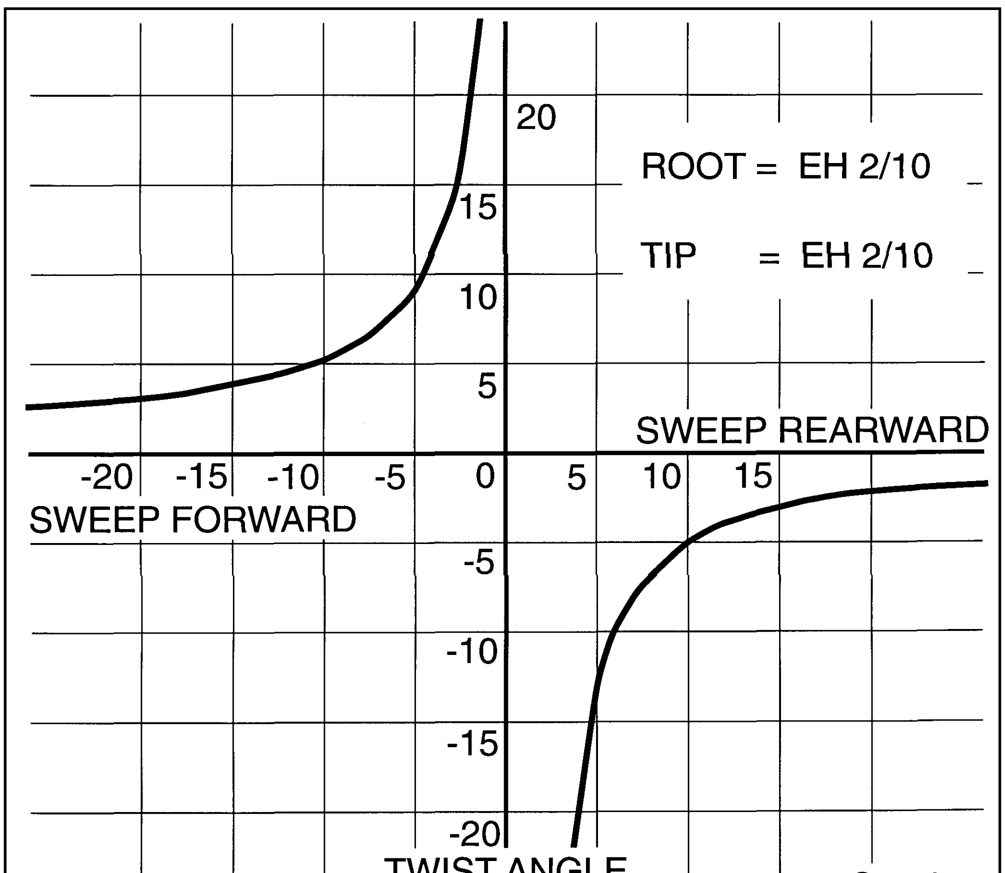
Graph 3 shows the startling effects of this simple change of tip section. The twist angle becomes 0° when sweep back is at about 17°, and actually becomes positive for larger sweep angles.

A surprising outgrowth of using the inverted E 205 for the tip section is the reduced twist required for the forward sweep configuration. This is due to the positive pitching moment of the inverted section. Note, however, that the required twist is approximately eight degrees for the case of 20^o leading edge sweep; this is probably beyond the point where the relatively flat upper surface will be stalled.

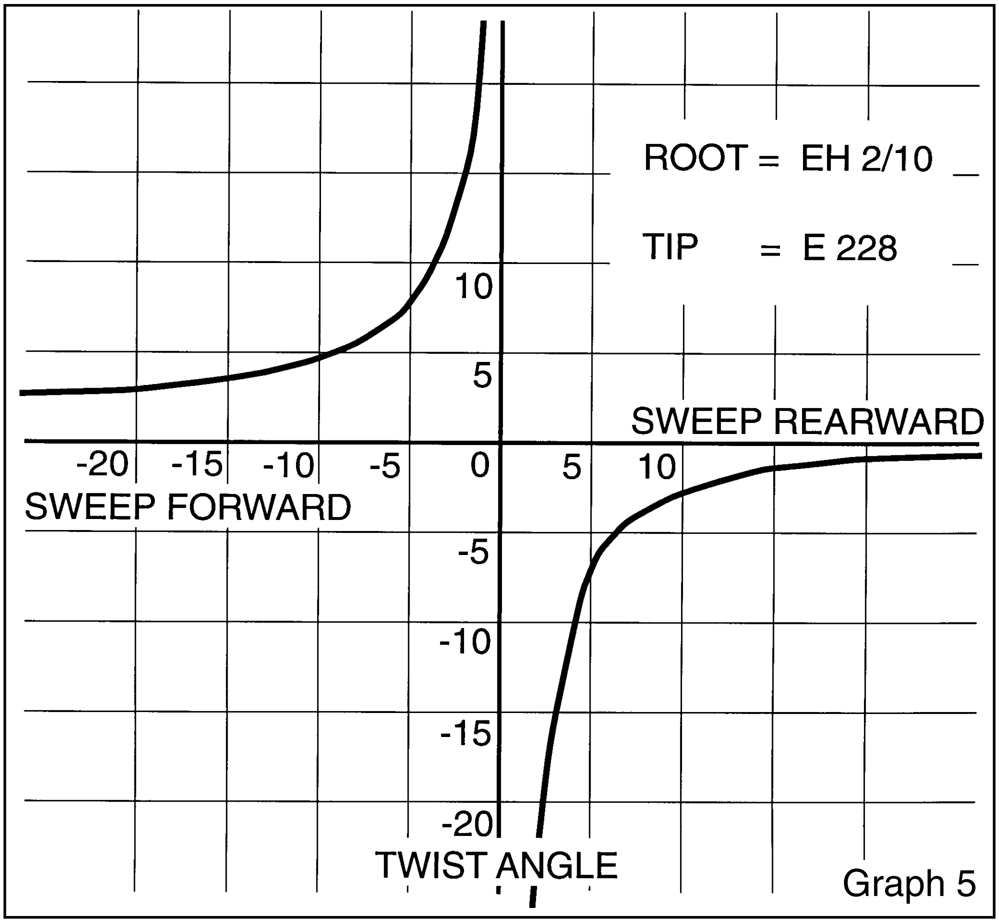
The relationship between pitching moment and required wing twist has been demonstrated to be an important consideration during the design process. As we've seen, a change of tip section can easily bring wing twist values down to manageable levels. However, using a root section with a very low pitching moment is an attractive alternative because very little twist will be required to obtain needed stability. The trick is to choose an airfoil with a near zero pitching moment which is capable of high lift. This is not possible with the symmetrical sections, but the EH series which we mentioned previously provides some excellent candidates.

We'll use the EH 2/10 for both the root and tip sections. (EH 2/10: C_m = 0.00165, α_{l0} = -0.74) Graph 4 depicts twist angle versus sweep angle for this airfoil combination.

Note the small twist angles required — about 25% of the twist angle required for the E 205 - E 205 combination. Additionally, we can anticipate very low drag for the EH 2/10 - EH 2/10 configuration, and, as is typical of low pitching moment airfoils, only very small increases in drag for various trim conditions.



Graph 4



We previously noted a reduction in required wing twist when the inverted E 205 was substituted for the E 205 as the tip section. If the EH 2/10 is used at the root and a section with a substantial positive pitching moment is used for the tip, we can predict a similar reduction in required twist. Graph 5 depicts the case in which the root section is the EH 2/10 and the tip section is the E 228. (E 228: C_m = +0.0143, α_{l0} = +0.34)

The E 228, with its slightly positive pitching moment, is capable of providing a large stabilizing force at very low wing twist values. We would therefore expect to see twist requirements diminish further if the E 230 were used as the tip section. (E 230: C_m = 0.025, the pitching moment advocated by Dr. Panknin rather than the value published in MTB 1/2, α_{l0} = 1.73)

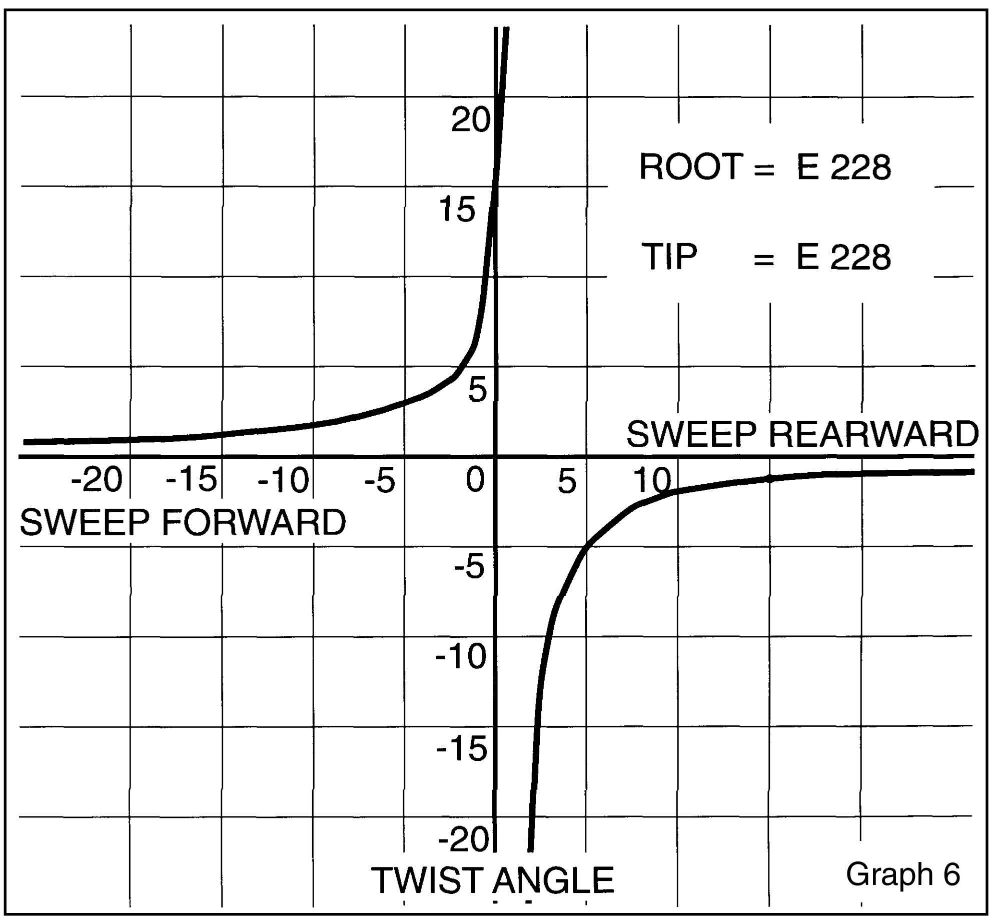
In Part 3 we’ll tackle the case of the plank — the nonswept ’wing — and present some conclusions.

Part 3

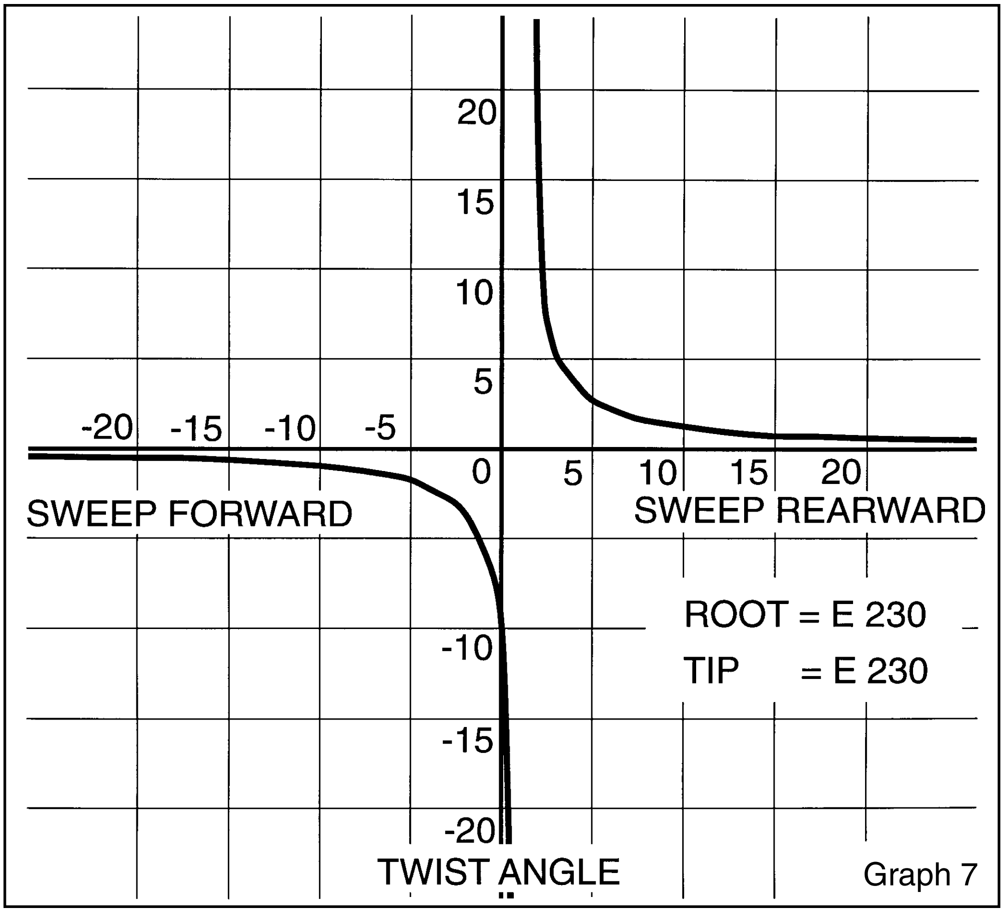
All of the graphs shown so far point to markedly increased twist angles as sweep angle decreases, and so on the surface it appears a plank planform, that is a wing with no sweep of the quarter chord line (-1.15 degrees leading edge sweep in our example), is not possible. However, by incorporating wing twist into the airfoil section itself we neatly overcome this seeming difficulty.

To see how this works, we will use two reflexed sections with slightly different pitching moments, the E 228 and the E 230. (E 228: C_m = +0.0143, α_{l0} = +0.34; E 230: C_m = +0.025, the pitching moment advocated by Dr. Panknin rather than the value published in MTB 1/2, α_{l0} = +1.73) See Graphs 6 and 7, respectively.

These two graphs provide an interesting bit of information. The E 228 (Graph 6) requires washout (trailing edge up) for rearward sweep, as would be expected from what we've seen previously. This indicates the E 228 is not stable enough for a plank configuration with the static margin we've chosen. On the other hand, Graph 7 demonstrates the E 230 is actually too stable.



Graph 6



The graph shows the E 230 requires washin (trailing edge down) for rearward sweep! To achieve a stability factor of 0.035, the wing tip must actually provide an up force if the wing is swept back, and a down force if the wing is swept forward — just the opposite of what we've seen in all of the previous examples.

A plank planform with a stability factor of 0.035 and no sweep of the leading edge would, therefore, require an airfoil with a pitching moment between that of the E 228 and the E 230, but closer to the E 230. As an exercise, we computed the pitching moment required for this plank planform and stability factor; it turned out to be 0.021, as was intuitively anticipated. As a point of interest, the E 230, when used with the unswept plank planform described above, requires a stability factor of 0.04167.

A few closing notes are in order.

- Bill chose the 100 inch wing span based on performance, ease of transportation, and a large number of viable construction methods. For those building other sizes, all linear dimensions can be easily proportioned, while all angles remain the same.

- We used a stability factor of 0.035 and an overall C_L of 0.6 for all of these examples. The required twist angle would increase in magnitude for a higher stability factor and larger C_L, and decrease in magnitude for a lower stability factor and smaller C_L value.

- While the stability factor is always directly related to both the location of the center of gravity and wing twist, changes in design C_L are related to wing twist only. We used a design C_L of 0.6 only for the purpose of constructing easily readable graphs. In the actual design process the C_L used in computations will be a fraction of this value and there will be an attendant lowering of the twist angle value.

- In practice, swept planforms have better performance than planks of the same dimensions. This is due to the inherent high drag of reflexed airfoils having markedly positive pitching moments. In designing a plank planform, therefore, you will want to use a reflexed section with no more reflex than necessary to provide a comfortable amount of stability. Additionally, swept wings tend to be more maneuverable than planks.

- Swept wings utilizing airfoils with pitching moments close to zero are now generally accepted to be the best performers, even though these sections do not have the lift capability of more conventional sections. A sweep angle of 15 to 20 degrees and a twist angle of less than four degrees are usually sufficient to provide needed stability when low pitching moment sections are used.

- For convenience, Table 3 provides the moment coefficient and zero lift angle data for the six airfoil sections mentioned in this series of articles
- The four basic concepts enumerated below should be an inherent part of the designer's knowledge base if an efficient design is to be the result.

  (1) increased stability (a more forward CG) requires more twist

  (2) a larger C_{mroot} requires more twist (We've now seen the C_{mtip} has an effect on the geometric twist required as well.)

  (3) increased sweep angle lessens the amount of required twist

  (4) a larger design C_L requires more twist

- As usual, we highly recommend readers explore avenues related to their own specific interests. This is an excellent learning environment which can provide much enjoyment.

- Lastly, a reminder for those of you with computers... Some time ago we wrote a BASIC program which determines both the required wing twist and actual location of the center of gravity as measured from the apex of the leading edge. The program is available in printed form in the Appendix, but takes just a matter of minutes to type in. The code is available in Microsoft QuickBASIC for IBM compatibles and for the Macintosh OS.

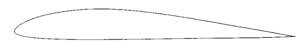
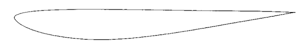
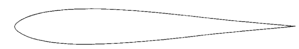
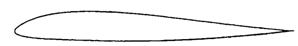
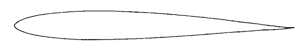
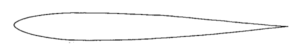
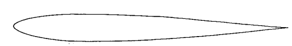
REF	DESIGNATION	C_m	$\alpha_{l=0}$	SECTION PROFILE
1	E 205	-0.046	-2.37	
2	E 205.inv	+0.046	+2.37	
3	Symmetrical	0.000	0.00	
4	EH 2/10	+0.00165	-0.74	
5	E 228	+0.0143	+0.34	
6	E 230.Eppler/MTB 1/2	+0.053	+1.73	
7	E 230.Panknin	+0.025	+1.73	

Table 3

In this series of articles we have attempted to explain how the location of the center of gravity, the pitching moments of the airfoils used, the chosen sweep angle, and the design lift coefficient dictate wing twist and overall pitch stability. We have tried to limit our discussion to pitch stability as it relates to only these variables. We thus have not discussed control surfaces. A number of readers have inquired about this topic and asked us to include information about control surfaces: their types, sizes, shapes, locations and ranges of deflection. These topics will therefore be explored in future columns.

Prior to publication in *RCSD*, we printed a copy of this article and gave it to Bill Kubiak for comment. Next month we'll share his thoughts on the material presented.

Part 4

Parts 1, 2, and 3 of this series were printed and given to Bill Kubiak for comment. At the World Soaring Jamboree in Richland Washington, we spent quite a few pool-side hours going over the material, assuring ourselves of both its accuracy and logical presentation. Bill had brought along a written summary of his thoughts, and in going over what he had written, we decided it should be shared with *RCSD* readers.

“In trying to use the curves for design, I concluded that the nearer the arms of the curve are to the axes, the better. This is because we are looking for a minimum amount of wing twist. I also conclude that the further down into the corner of the X - Y axis the curves penetrate, the better. This is because we are looking for a reasonable sweep angle.

GRAPH #	ROOT SECTION	TIP SECTION
Graph 1	symmetrical	symmetrical
Graph 2	Eppler 205	Eppler 205
Graph 3	Eppler 205	inverted Eppler 205
Graph 4	EH 2/10	EH 2/10
Graph 5	EH 2/10	Eppler 228
Graph 6	Eppler 228	Eppler 228
Graph 7	Eppler 230	Eppler 230

“I had considerable trouble trying to compare one airfoil section to another, so I ran over to my favorite Mail Box and had transparent copies of your curves made. Then I laid the transparency of Graph 1 over that of Graph 4 and copied them onto plain paper. That’s better; now I can compare these two sections of similar (almost zero) C_m. I see that there is little to choose from between the two, at least as far as C_m is concerned. L/D should be looked at. I suspect the EH 2/10 will be better. After all, that’s the *raison d’etre* for camber, isn’t it?

“Then I stacked the transparencies of Graphs 1, 2, and 3 to see how a cambered section compared to a symmetrical section. Wow! I assume whatever the merits of the basic section are, if #3 is used, it being so far from the axis, trim drag will be excessive compared to #1. That’s why twisting a wing with a conventional cambered section just doesn’t work — the trim drag is too high. Now I understand, while before I didn’t. When you compare Graph #3 to both Graph #2 and Graph #1, you see that changing camber is a more effective method of controlling C_M (pitching moment of the entire aircraft) than twist is.

"You could tune, through iteration, a design to fit a specific static margin by keeping a portion of the center section untwisted and just twisting the outer portion until the trim forces just balanced the static margin. However, the graphs show it is as easy to invert the tip section as to twist the wing.

"If a wing is built using the conventional hot wire and foam method, it is given a linear twist. I now realize that only the center line and the tip of such a wing will have known aerodynamic characteristics. In the case depicted in Graph #3, where the tip is inverted, the centerline section will gradually transition to a symmetrical section at near mid-semispan, which will then transition to the inverted section at the tip.

"Since every airfoil section has a design C_l, and you wish the design section C_l could be equal to the design C_L (whole aircraft) for minimum drag, it seems that for least drag for a given lift, as much of the wing should be untwisted as possible. Most of the wing is then flying at a constant C_L, hopefully at the design $C_{L.}$

"Now that I've decided that twist by itself is not the most efficient way of controlling the overall pitching moment (C_M), it makes sense to adopt the concept of inverting the tip section. At the time that you mentioned this to me I thought it was a real hokey way to solve a problem. Now I see that you could have the center section flying at its best design C_l, the tips flying at their best inverted design C_l, and the whole aircraft would be flying at the desired C_L.

"With all of this in mind, and when speaking of swept back wings, it seems what is very much needed is a root section with very low pitching moment but high C_{lmax}. The EH 2/10 is a far better choice for this application than a symmetrical section because it is capable of much greater lift with very little drag penalty. Since the root airfoil has a pitching moment near zero, the normal down force required by the wing tips is not great. On the other hand, you would want a tip section capable of high lift as well, since a strong up force is needed to right the aircraft in pitch following a stall of the center section. This leads me to believe it is best to choose an airfoil which meets all of these criteria and can be used across the entire span. My choice would be the EH 2/10."

References:

Eppler Profile, MTB 1/2; Verlag für Technik und Handwerk GmbH, Postfach 2274, 76492 Baden-Baden Germany.

Kuhlman, Bill and Bunny; “On the 'Wing..., the book”; B^{2}Streamlines, P.O. Box 976, Olalla WA 98359-0976.

Lichte, Dipl.-Ing. Martin; “Nurflügel-modelle,” VTH Modellbaureihe Band 3; Verlag für Technik und Handwerk GmbH, Postfach 2274, 76492 Baden-Baden Germany.

Panknin, Dr. Ing. Walter K.; “Proceedings, 1989 MARCS Symposium”; Allan Scidmore, 5013 Dorsett Drive, Madison WI 53711.

Tailless forever!

— Hans-Jürgen Unverferth

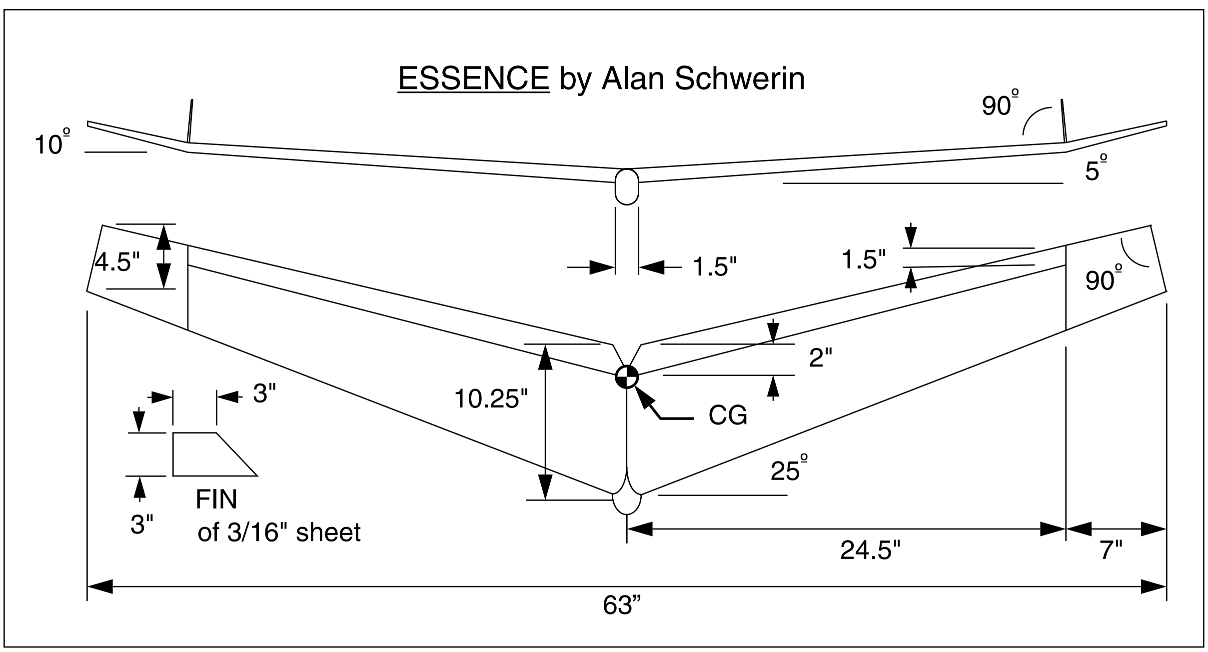
Alan Schwerin's "Essence"

Dr. Alan Schwerin, of Lake Charles Louisiana, wrote to tell of his latest project, a swept 'wing which he calls "Essence." This 'ship, his second 'wing, has several characteristics which will be of interest to tailless enthusiasts.

Alan used the SD 7037 as the root section and the SD 8020 for the tip. The transition from one airfoil to another is linear across the semi-span. Neither of these airfoils is generally considered to be appropriate to tailless applications, but the combination seems to work very well for this planform. Lateral stability is achieved through use of enlarged fences. These fins are three inches high and are outboard, at about 80% of the semi-span.

Alan put five degrees of dihedral into the wing's center panels, and ten degrees of dihedral into the outer panels. Dihedral usually makes winch and high start launching difficult, but this has not been the case with "Essence" — it high starts very easily.

"Essence" is constructed of blue foam which has been sheeted with obechi. An Airtronics micro receiver, two micro servos, and a 100 mah battery make up the flight pack. Elevons serve as the only control surfaces. These extend



out from the root to the fins, and the roll rate is excellent. A minimal fiberglass keel provides a hand hold and houses and protects all of the radio gear. Total weight is 17 ounces, but with an area of 450 in^2, the loading is down to 5.44 $oz./ft^2$.

“Essence” started out as an RC-HLG, but it was soon discovered that, despite its relatively low wing loading, its ability to circle was not nearly adequate for HLG contests. “Essence” does, however, have a rather broad speed range, and is capable of flying nearly as slowly as an Eppler 387 equipped RC-HLG of conventional tailed configuration. This makes for a lot of leisure flying fun.

Alan concluded his letter with the following observation; “There are so many negative comments in the literature about ‘wings and their inefficiencies, I had to find out for myself. I am not entirely sold on ‘wings, but the fun of trying out one’s own ideas, over very high grass, appeals to me.”

Kelly McCombs' Kevlar Hinge

A few months ago we presented a spar system developed by Kelly McCombs of Fruit Heights Utah. In this month's column we'll describe a Kevlar fabric hinge system which Kelly uses in composite structures.

Many builders use Kevlar as a hinge material, but most have found hinge failure after several hundred cycles. This is because the epoxy penetrates the fabric during the vacuum bagging process, producing a brittle matrix which rapidly fatigues. What is needed is commonly called a resist — a material which will prevent the epoxy from penetrating the Kevlar, leaving the fabric in its original state, free to flex. Surprisingly, the resist which Kelly uses is a common grease pencil, as used for marking china and glass! A detailed description of the entire process is outlined below:

- Mark the hinge line with a pen or pencil. Be sure to mark the top, bottom, and both ends.

- Apply one layer of Kevlar fabric to the hinge line using 3M "77" spray.

- Using the grease pencil, mark a 1/4 inch wide area directly over the hinge line. Choose the color of the grease pencil carefully, as you will want to have good contrast between the grease pencil marking, the yellow Kevlar fabric, and the carbon fiber which will be added in the next step. Kelly suggests red or blue rather than yellow, black or green.

- Apply a single 12K tow of carbon fiber over the hinge line using 3M "77" spray. A portion of this material will be removed in a later step, but what remains will reinforce the hinge line.

- Apply fiberglass cloth to the entire structure, including the control surface. Use 3M "77" spray, or follow your normal construction practice.

- Vacuum bag as usual.

- Once removed from the vacuum bag, cut a V groove into the structure on the side opposite the hinge. This groove provides the clearance necessary for proper hinge movement, so it should go all the way through to the Kevlar hinge material.

- Flex the control surface so the V closes completely. Using a razor blade held vertical to the hinge line, scrape away the fiberglass and carbon fiber until the grease pencil line is just visible.

- The control surface hinge is now complete.

This process, with appropriate modifications, can also be used by builders who prefer to construct the leading edge of the control surface and the trailing edge of the main surface prior to ‘glassing.

An added tip... If a length of music wire is imbedded in the leading edge of the control surface, the CG of the control surface will be shifted forward, inhibiting flutter.

Kelly included a small sample of a completed Kevlar hinge produced using the above described techniques. The resulting hinge is extremely strong and very flexible. As is usual with any new construction method, this technique should be tried out on scrap materials at least once before being applied to a model structure.

Alfons Rieger's "Nurflügelprofils"

Alfons Rieger's tailless sailplanes have appeared in "Faszination Nurflügel," and *Flüg- und Modelltechnik* and *Aufwind* magazines. These models, of the numbered "Sirius" series, are all of plank planform and designed primarily for slope flying.

In an effort to achieve incremental performance improvements, Mr. Rieger has taken to designing his own reflexed airfoil sections. The AR 193-S75 is based on the Eppler 193, while the AR 2411-S77 was initially based on the Eppler 205. The AR 2610-S80 is entirely of Mr. Rieger's own design. All three sections have been used successfully. Despite their thickness, they exhibit relatively low drag at Reynolds numbers of 150,000 and above, and are capable of producing large amounts of lift with good stall characteristics.

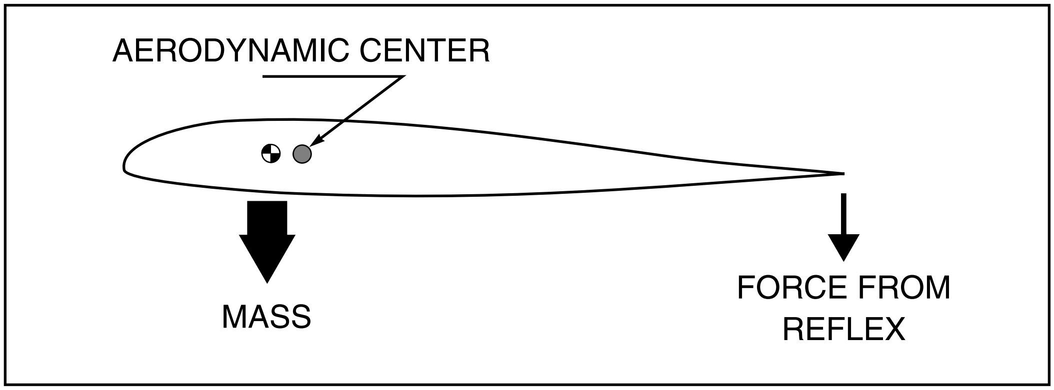
The aft portion of each section's camber line has been reflexed to achieve a substantial positive pitching moment. The crossover point is at the percent chord denoted by the number following the "S." Zero lift angles, moment coefficients, percent camber and percent thickness for each section are noted within the included data table.

The camber line of most "self-righting" airfoils is of an "S" shape. For dynamic stability, the center of gravity must be forward of the mean aerodynamic chord (MAC), and the reflexed portion of the airfoil must provide sufficient downforce for the airfoil's pitching moment to be positive.

While the amount of reflex camber has a direct effect upon the pitching moment, the shape of the camber line ahead of the crossover point is important as well. If the goal is to modify a conventional section to achieve a specific pitching moment, a highly cambered section will require more reflex than a symmetrical section.

The usual practice when designing sections for plank planforms has been to place the crossover point at 75% chord. Fully 25% of the section's chord is then devoted to overcoming the strong negative moment generated by the forward portion of the camber line.

When the crossover point is moved back to the 80% chord point, the percent camber of the reflexed portion of the section will need to be much greater if the pitching moment is to be held constant. Such sharp changes in the



camber line are not usually desirable, as the surface develops sharp curvatures and the possibilities for flow separation increase dramatically. As can be imagined, flow separation over any part of the stabilizing portion of the airfoil will most likely lead to disaster.

There are instances, however, where strong positive pitching moments are not required, or where the forward camber is low enough that not much reflex is required to achieve the needed pitching moment. In these cases, the crossover point can be safely moved rearward and the camber of the reflexed portion reduced to maintain a smooth camber line. Reducing the reflex usually lowers section drag.

These three sections demonstrate how the camber line reflex point and the amount of camber in the reflexed portion of the section can be adjusted to provide a required moment coefficient without unnecessarily increasing drag.

The camber line of the AR 193-S75 (C_m = +0.058) crosses the mean chord line at 75% chord, while the camber line of the AR 2411-S77 crosses the mean chord line at 77% chord (C_m = +0.027). The camber line crossover point of the AR 2610-S80, on the other hand, is at 80% chord, and its positive pitching moment is lower still (C_m = +0.026). It should be noted that the AR 2610-S80 would not usually be considered for use on a plank planform, yet Alfons has used it as the sole section for his Sirius 90 which performs extremely well.

Reflexed sections with large amounts of camber may sometimes benefit from artificial turbulation — at about 10 to 15% chord on the upper surface, and just forward of the crossover point on the lower surface. Sections such as the three described here, designed for the relatively high Reynolds numbers of slope flying (Re_{min} = 150,000), may then be suitable for the thermal-duration environment.

	AR 193-S75	AR 2411-S77	AR 2610-S80
$\alpha_{l=0}$	1.068°	0.11° *	-0.15°
C_m	0.058	0.027 *	0.026
camber	2.47%	2.33%	2.57%
thickness	10.23%	10.82%	10.0%

* = datum determined via Walt Lounsbery's computer program, SoarTech 1.

References:

AR 2411-S77, Personal communication, Alfons Reiger. October, 1994.

AR 2610-S80 — Ein Optimiertes Profil für Brettnurflügel, *Aufwind* June 1990 pp. 30-31. MIBA-Verlag, Werner Walter Weintötter GmbH u. Co., Schanzäckerstrasse 24-26, D-8500 Nürnberg 70, Germany.

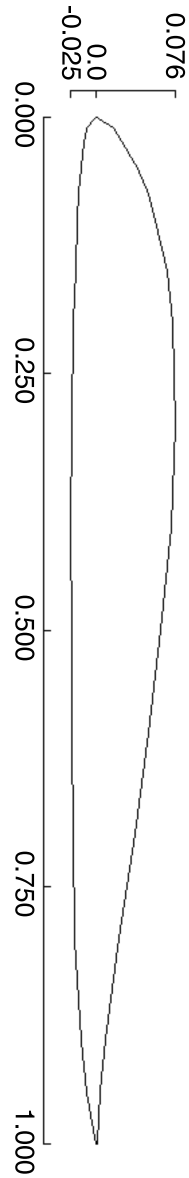
"Faszination Nurflügel," Hans-Jürgen Unverferth, Editor. Verlag für Technik und Handwerk GmbH, Postfach 2274, D-76492 Baden-Baden Germany, 1989.

Nurflügelprofil AR 193-S75, *Flug- und Modelltechnik* October 1988 p. 25. Verlag für Technik und Handwerk GmbH, Postfach 2274, D-76492 Baden-Baden Germany.

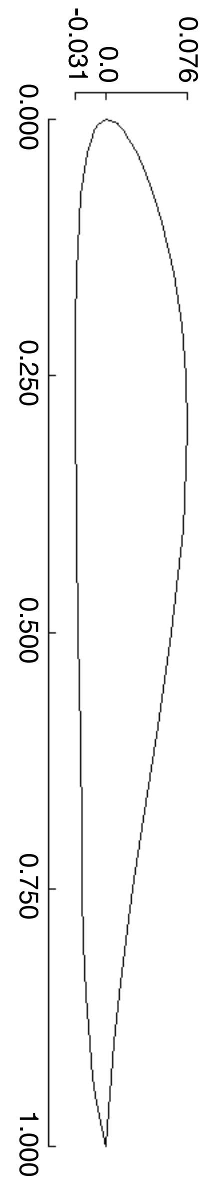
Nurflügelprofile?, *Flug- und Modelltechnik* May 1988 p. 18. Verlag für Technik und Handwerk GmbH, Postfach 2274, D-76492 Baden-Baden Germany.

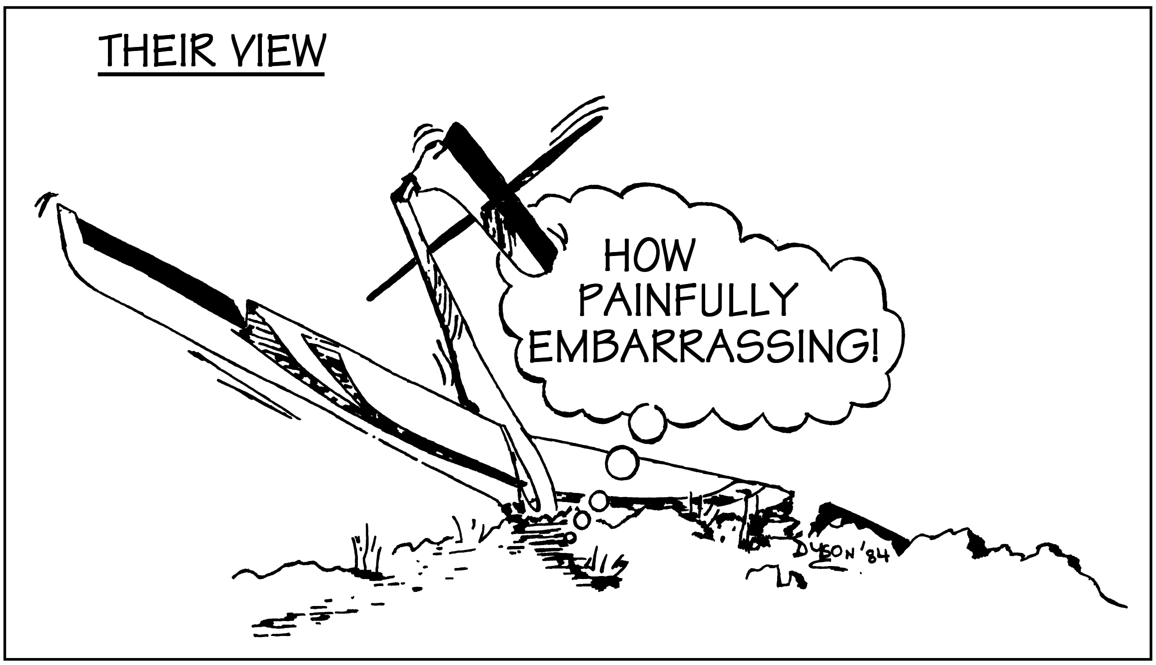
Simple Calculation of Airfoil Moment Coefficients, Walter Lounsbery. *SoarTech 1*, Herk Stokely, Editor. Herk Stokely, 1504 Horseshoe Circle, Virginia Beach VA 23451.

AR 2610-S80			
X upper	Y upper	X lower	Y lower
0.0	0.0	0.0	0.0
1.25	1.73	1.25	-1.035
2.5	2.58	2.5	-1.265
5.0	3.925	5.0	-1.535
7.5	4.955	7.5	-1.715
10	5.69	10	-1.85
15	6.76	15	-2.04
20	7.29	20	-2.235
30	7.55	30	-2.45
40	7.17	40	-2.51
50	6.15	50	-2.45
60	4.95	60	-2.40
70	3.65	70	-2.25
80	2.09	80	-2.09
90	0.815	90	-1.55
95	0.36	95	-0.94
100	0.10	100	-0.10



AR 2411-S77			
X upper	Y upper	X lower	Y lower
0.000	0.000	0.000	0.000
0.5	1.042	0.5	-0.736
1.25	1.710	1.25	-1.209
1.7	2.035	1.7	-1.410
2.5	2.510	2.5	-1.676
3.5	3.020	3.5	-1.920
5.0	3.685	5.0	-2.193
6.7	4.350	6.7	-2.415
7.5	4.636	7.5	-2.500
10	5.408	10	-2.715
15	6.553	15	-2.977
20	7.280	20	-3.080
25	7.670	25	-3.100
30	7.816	30	-3.050
37.06	7.637	37.06	-2.925
40	7.430	40	-2.875
50	6.351	50	-2.737
60	4.900	60	-2.587
70	3.314	70	-2.432
75	2.534	75	-2.350
80	1.829	80	-2.208
85.3	1.180	85.3	-1.990
90	0.700	90	-1.683
93.3	0.430	93.3	-1.323
95	0.312	95	-1.073
98.3	0.126	98.3	-0.425
100	0.000	100	0.000





From “Aspectivity,” of the Victorian Association of Radio Model Soaring, Australia, and the pen of Cameron Dyson, via DELTA #4, Reinhard Werner, Editor

A Graphical Method of Determining the Neutral Point and Center of Gravity

The center of gravity (CG) is defined as the center of mass. If suspended by the CG in a gravitational field, an object will remain motionless regardless of orientation. The pitch stability of an aerodyne is directly linked to the location of the CG in relation to the neutral point (NP), the quarter chord point of the mean aerodynamic chord (MAC).

If the CG is ahead of the NP, the aerodyne will be stable in flight, and moving the CG further forward will always make the aircraft more stable. There will invariably be an associated change in decalage or, in the case of swept tailless aircraft, a change in wing twist. As the CG is moved back toward the NP the pitch forces generated by the elevator become more effective.

If the CG is at the NP, the aircraft will be neutrally stable. That is, the pitch attitude of the aircraft will not change if the elevator is not deflected. The term neutral point is derived from this behavior.

If the CG is behind the NP, the aerodyne will be unstable in pitch. While this condition may enhance maneuverability or some other performance factor for a full sized aircraft, it is something to be avoided by modelers. A full sized aircraft in this state may be flyable by an experienced pilot, but a model aircraft in this state may not be flyable at all. If the CG is substantially behind the NP, some sort of active control system will be necessary for sustained flight. Redundant computer systems take care of maintaining pitch stability in the B-2 Stealth bomber and NASA's X-29 research vehicle, both of which are inherently unstable.

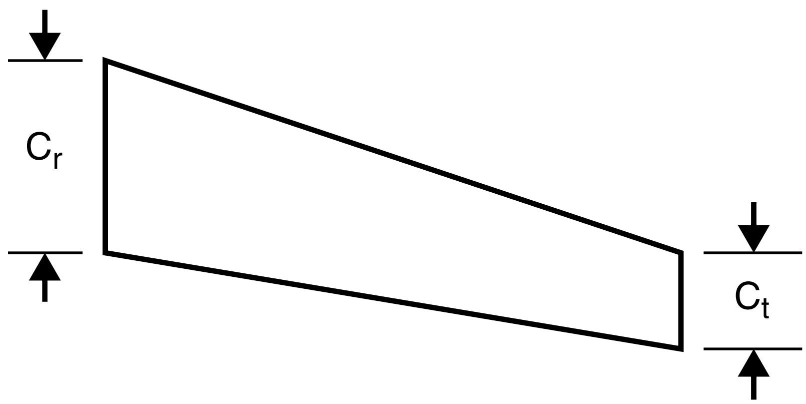
We certainly do not want to winch launch and attempt to fly an unstable aircraft, so there can be no denying the importance of pitch stability. Yet the usual methods for assuring ourselves of a safe balance point — CG ahead of NP — involve quite a bit of relatively complex mathematics. There has to be a better way, and so there is. We'll describe here a graphical method of finding the neutral point which works for any tailless planform.

Before flying your latest tailless creation, make sure the CG is in front of the NP!

To start, draw out one complete wing on a piece of paper. This can be either a full size tracing, or drawn to some scale with which you feel comfortable. By following the simple directions outlined here, you can easily find the NP of either single or multipanel wings without resorting to mathematics of any kind.

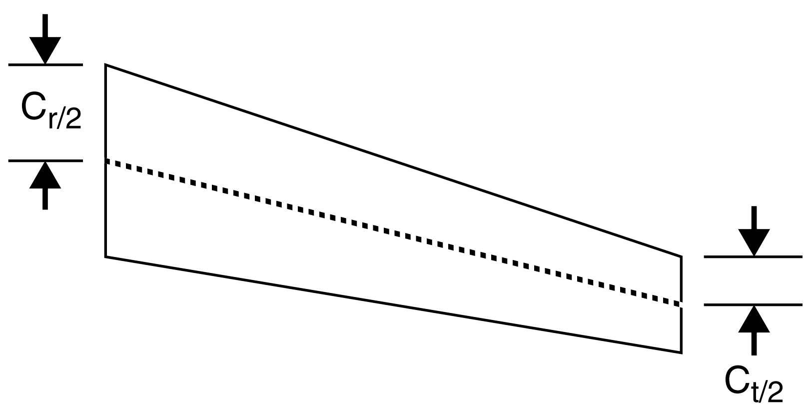
<u>Step 1</u>

- Identify end chords of panel as root chord, C_r, and tip chord, C_t.



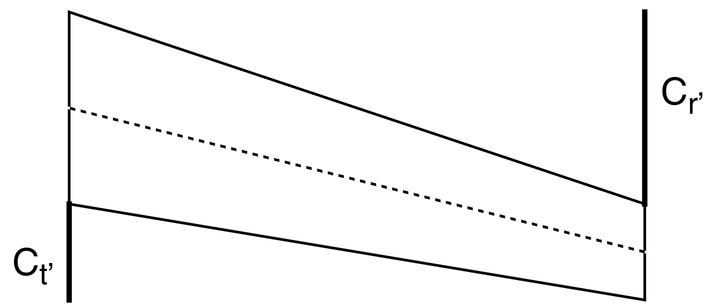
<u>Step 2</u>

- Find and mark midpoints of C_r and C_t.
- Connect the two points. This is the half chord line.



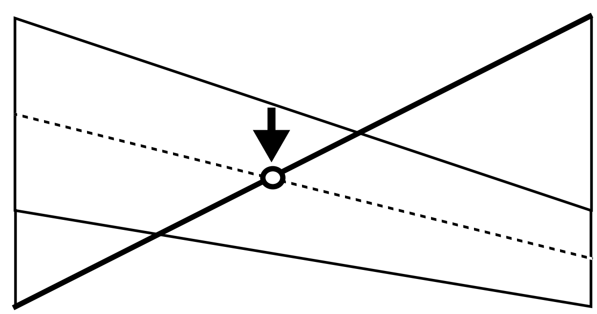
Step 3

- Draw C_r extending from the leading edge of the wing tip, forming C_r'.
- Draw C_t extending from the trailing edge of the root, forming C_t'.



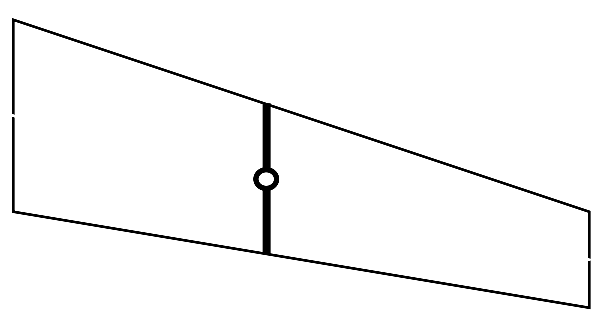
Step 4

- Draw a diagonal line from the end of C_r' to the end of C_t'.
- Mark the intersection of this line and the half chord line.



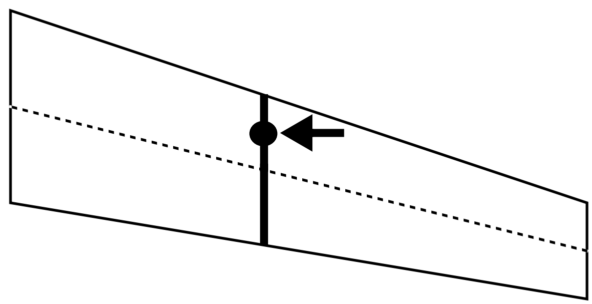
Step 5

- Draw a line through the point drawn in Step 4. This line must be parallel to C_r and C_t. This is the geometric mean chord.



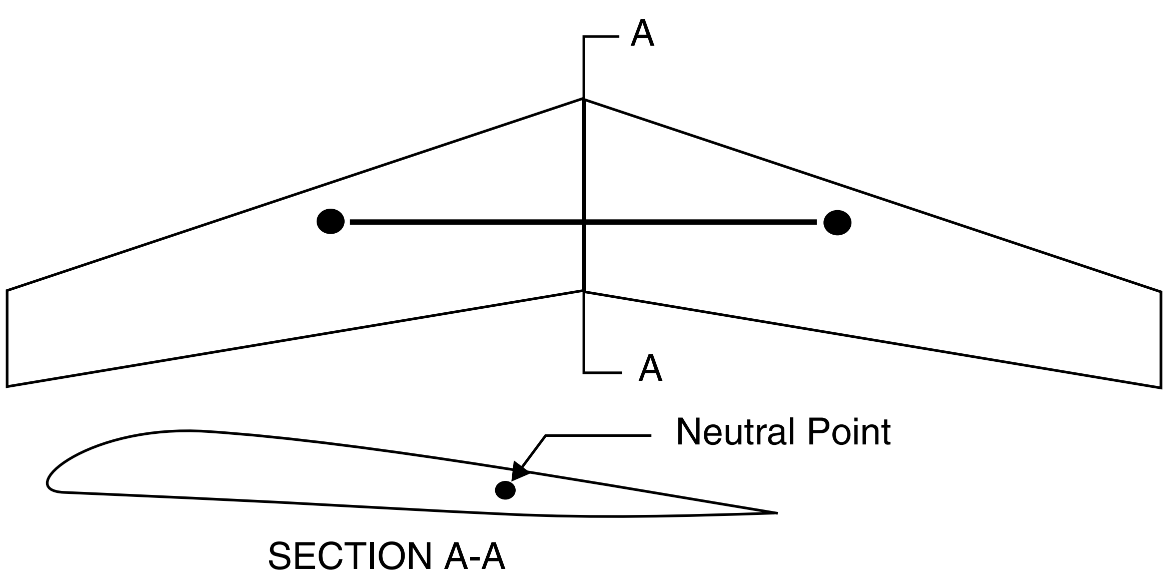
Step 6

• On the geometric mean chord, mark the midpoint between the leading edge and the half chord line. This is the Neutral Point of this wing panel - 25%MAC.

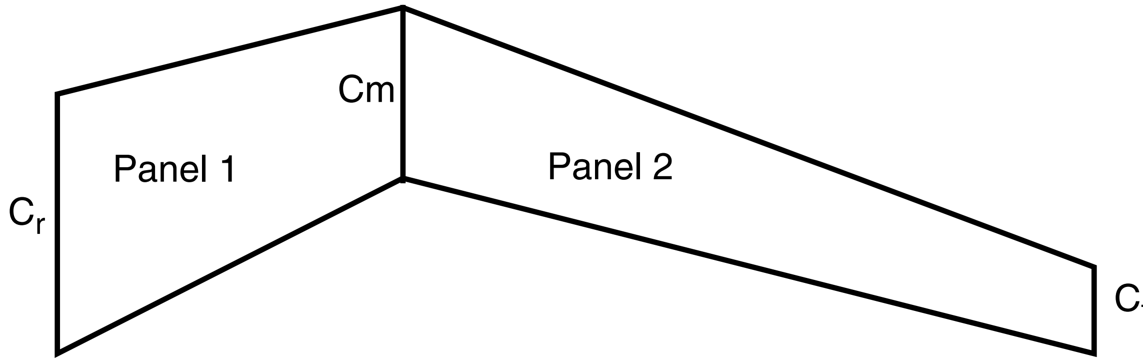


Step 7

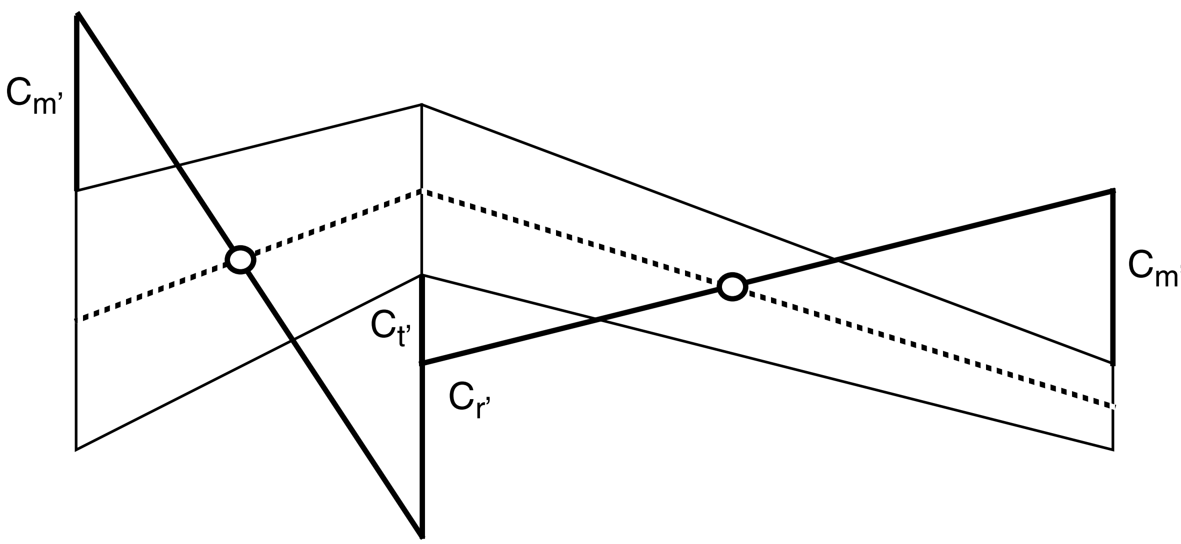
• Draw a line connecting the Neutral points of the left and right wing panels. This provides an intersection with the center line.
• The Neutral Point is then easily projected onto a side view of the root chord.



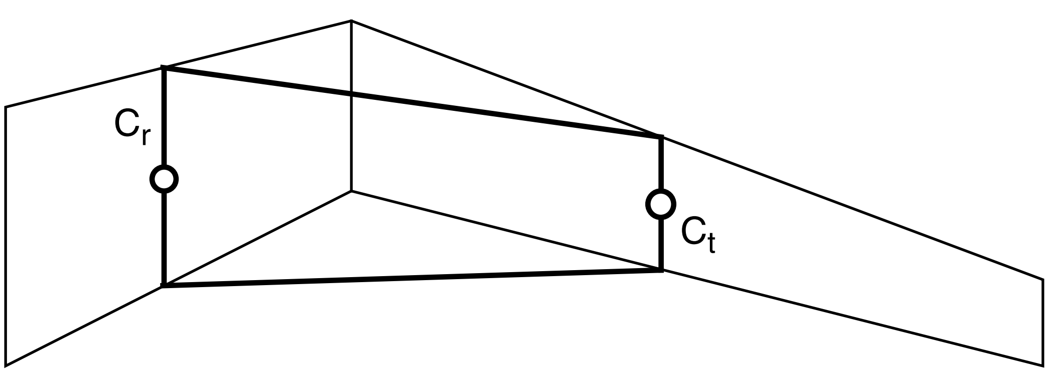
For a multi-panel wing, start with Step 1 and identify all chords which define the entire wing.



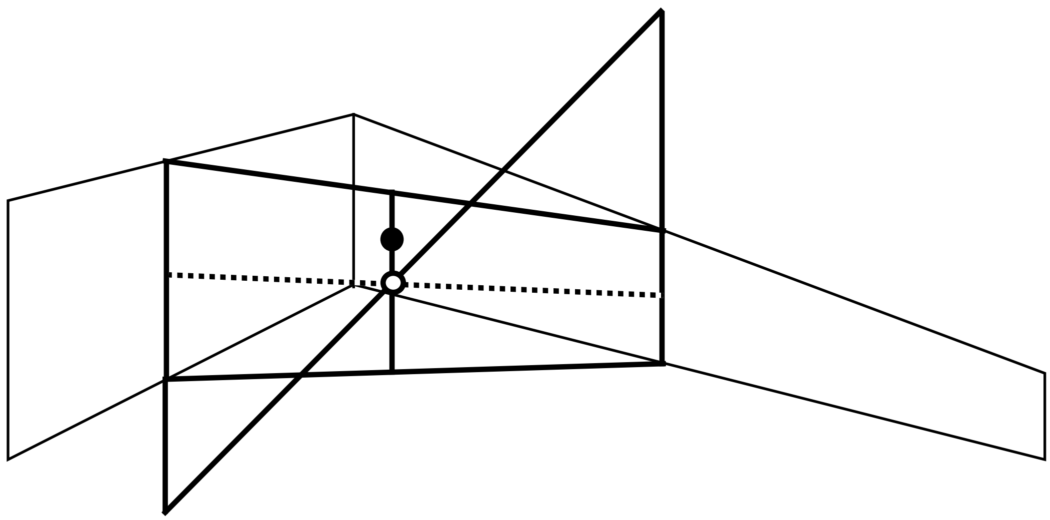
Follow with Steps 2, 3, and 4 for both panels. Since panel 1 sweeps forward, Cr' and Cm' are relocated to trailing edge and leading edge, respectively. This brings the intersection closer to a 90^o angle. (Pretty tricky, eh?)



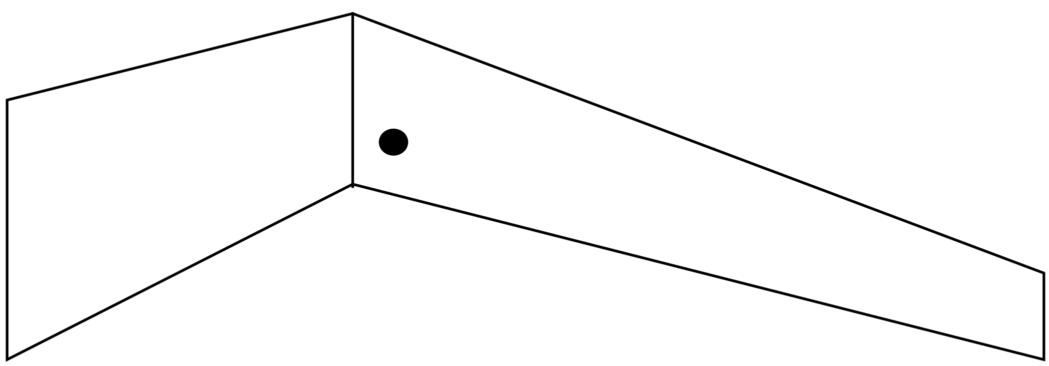
With Step 5, connect the newfound chords with artificial leading and trailing edges.



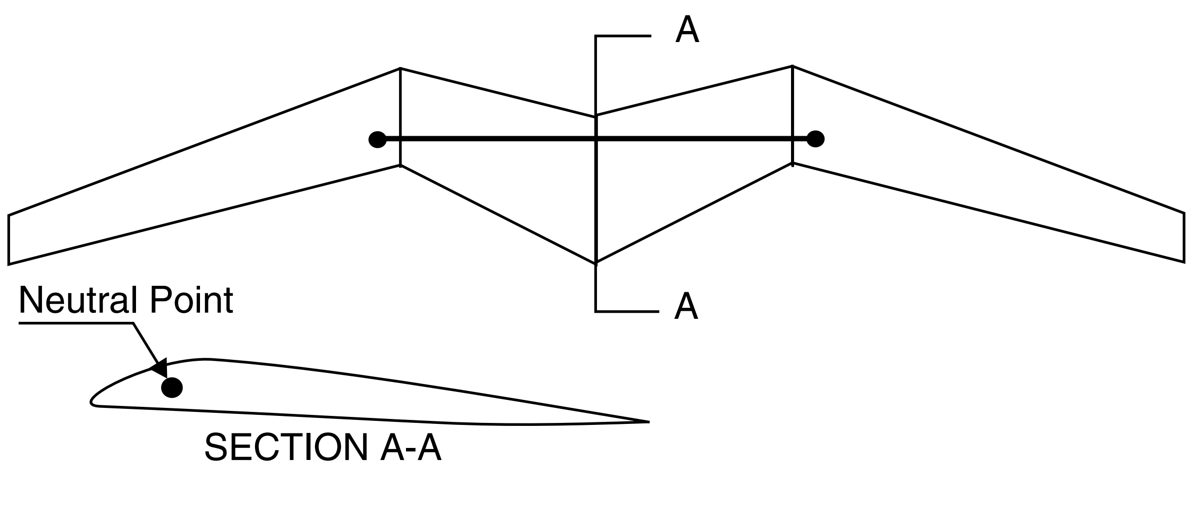
Follow Steps 2, 3, 4, 5 and 6 for this single panel.



This is the Neutral Point of the entire right wing.

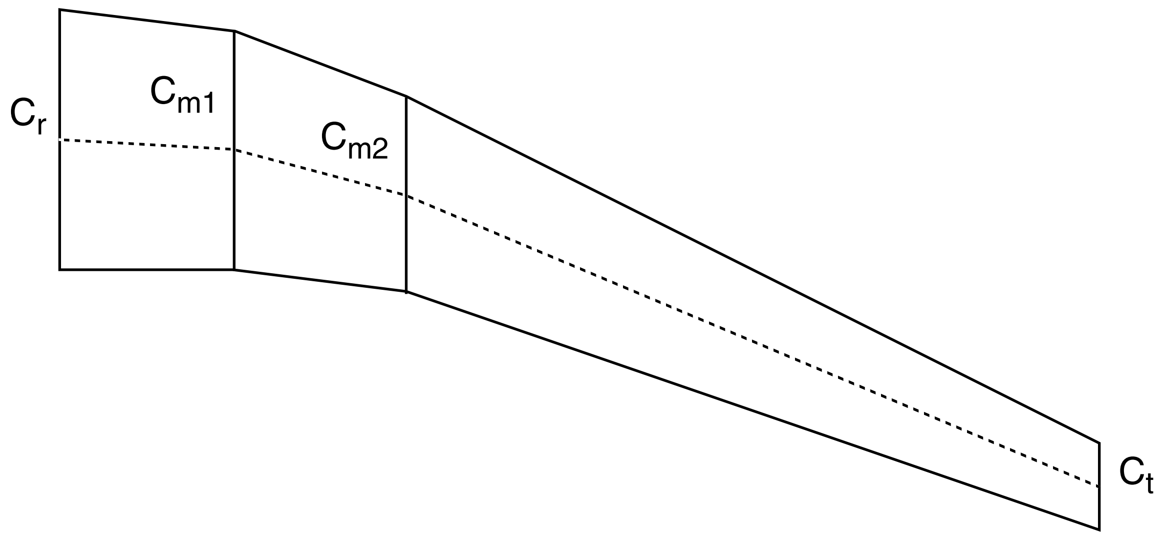


Performing Step 7 gives the Neutral Point for the entire wing and allows for projection onto the side view of the root.

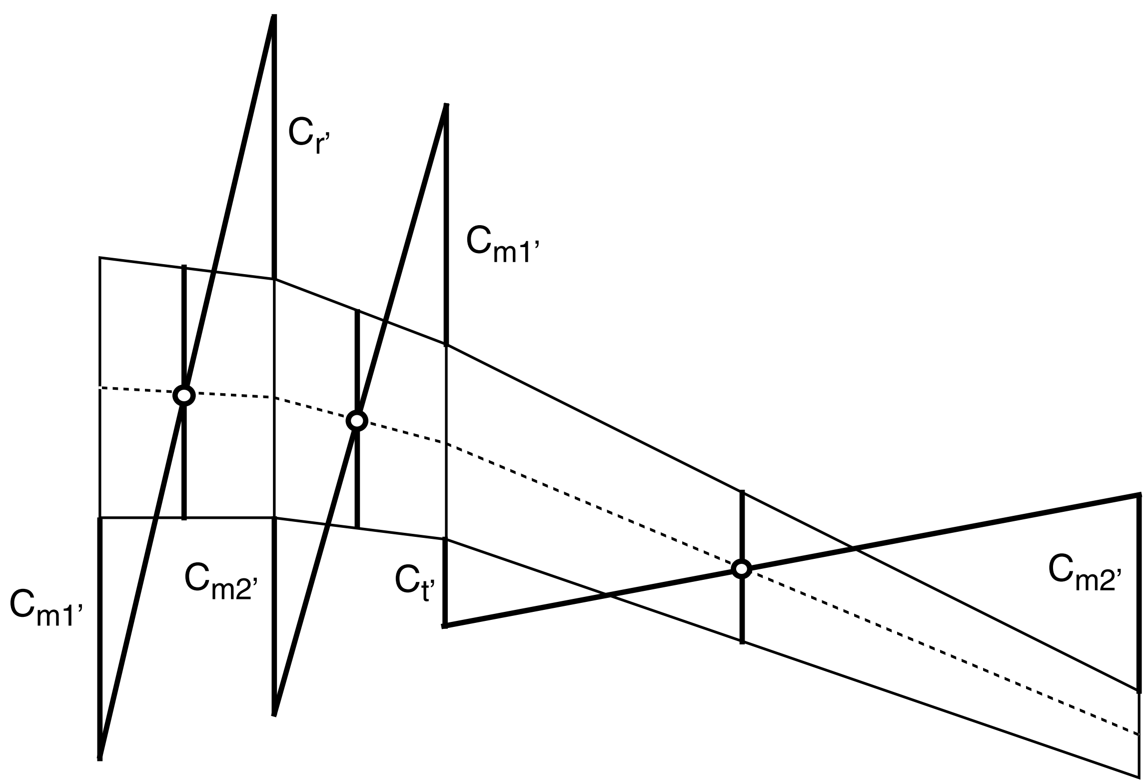


SECTION A-A

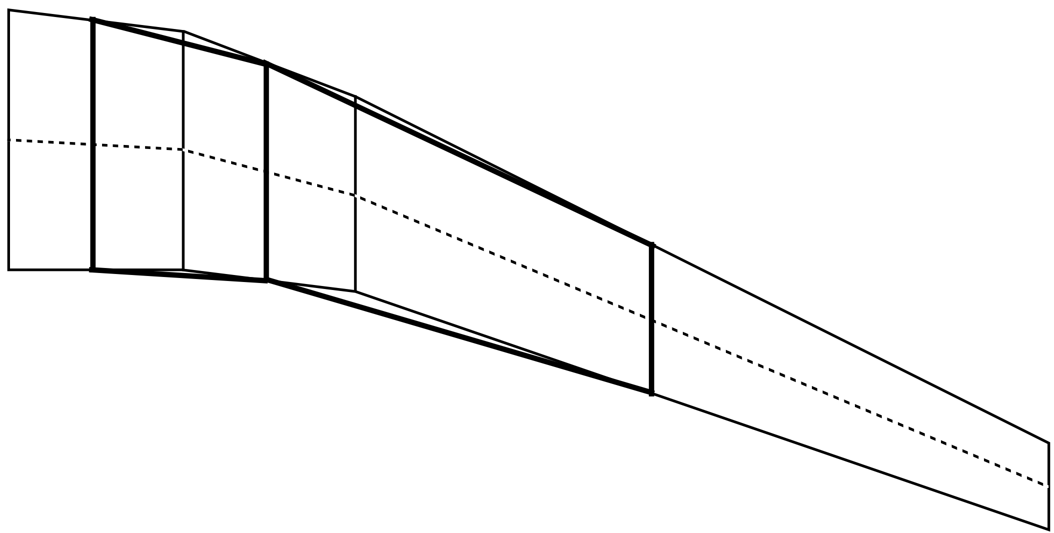
This wing is similar to that of the Akafleig Braunscheig SB-13. Begin with Steps 1 and 2...



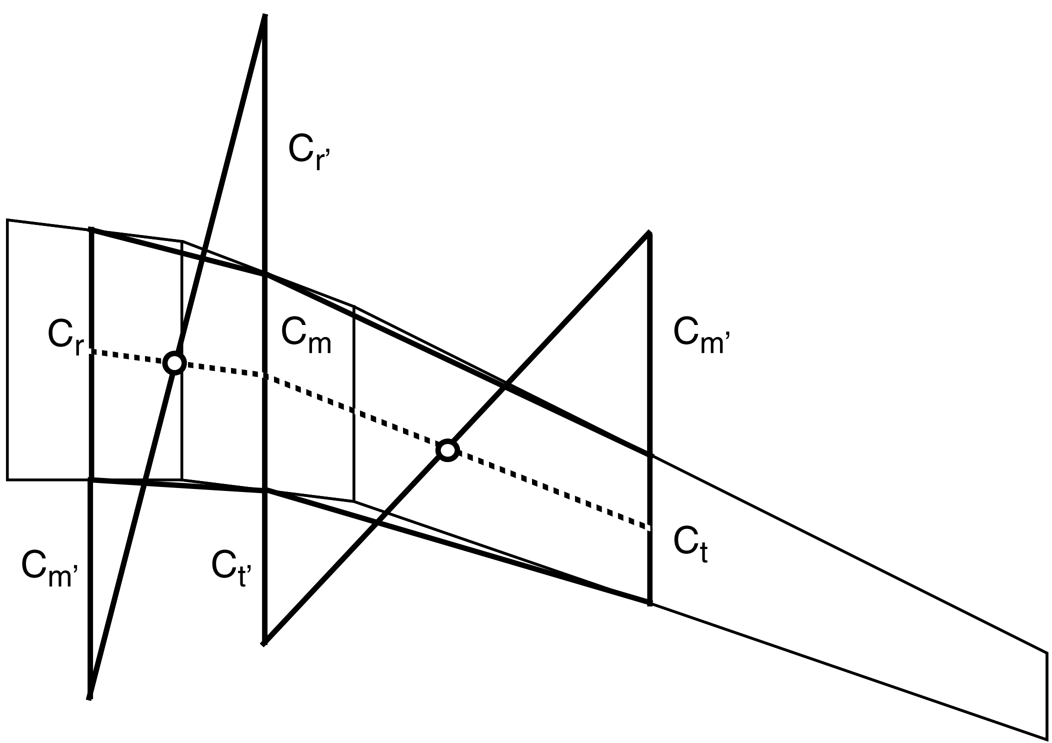
Follow with Steps 3, 4, and 5...



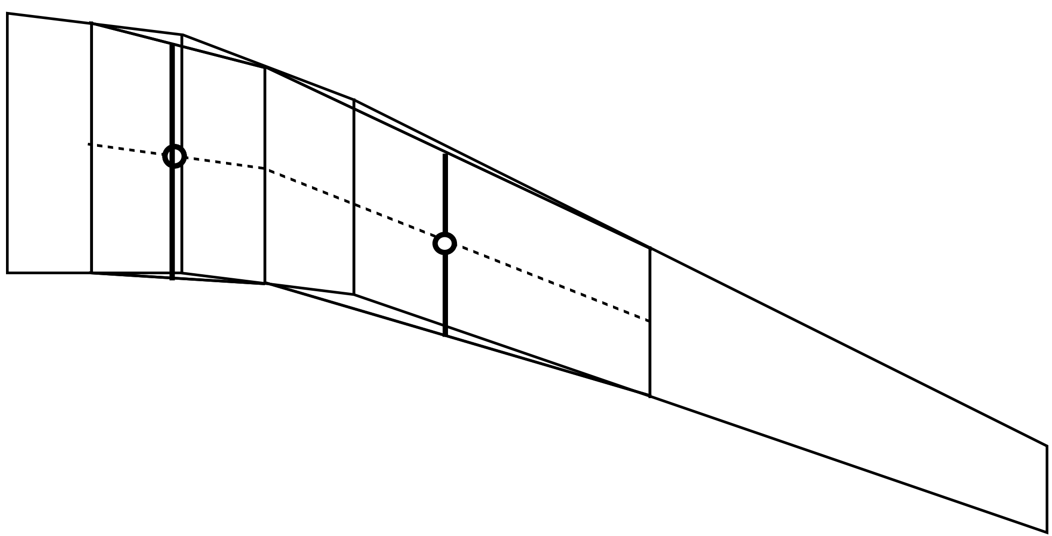
Then connect the new chords with artificial leading and trailing edges, just as before...



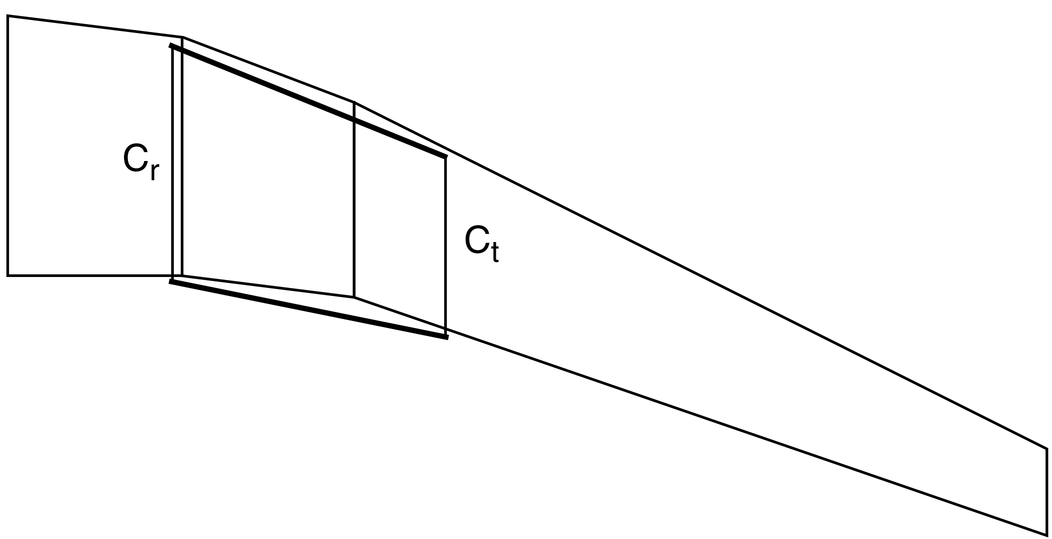
Follow with Steps 1, 2, 3, 4, and 5 using the resulting panels from the previous operations...



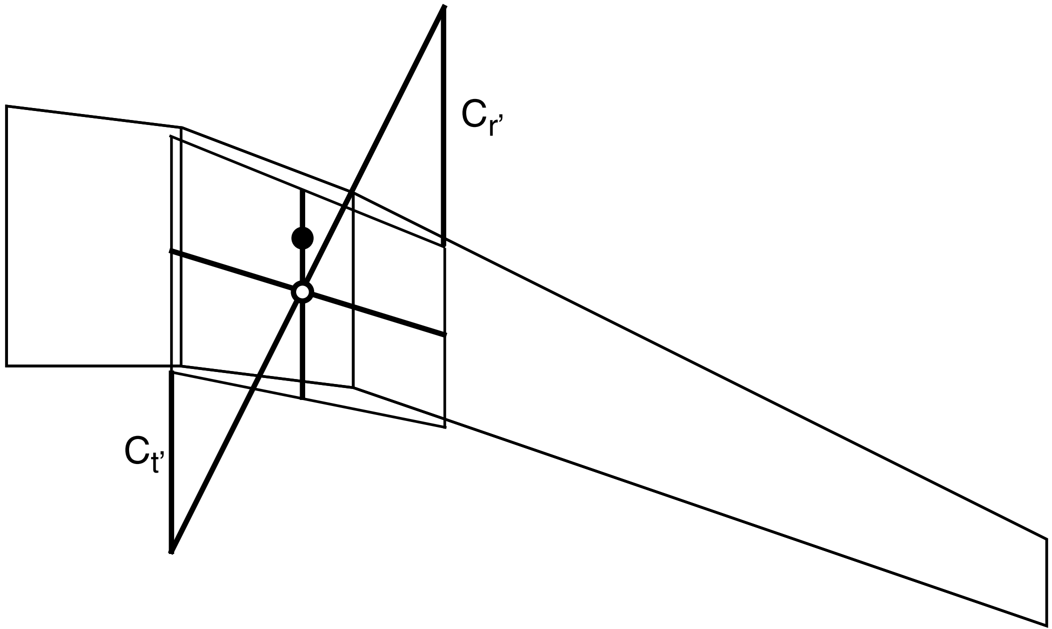
Perform Step 6 for both panels...



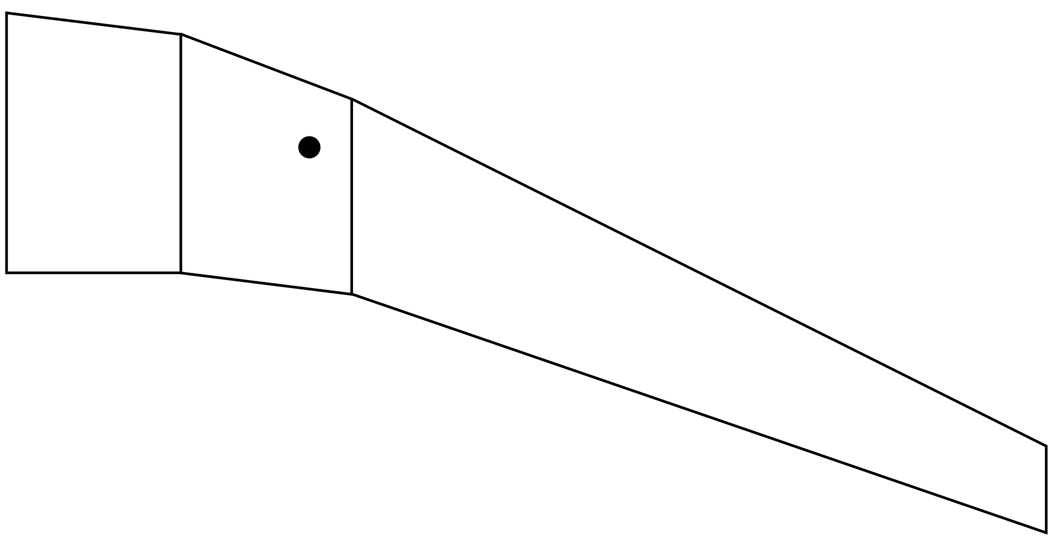
And connect the new chord lines with artificial leading and trailing edges.



Perform Steps 1, 2, 3, 4, 5, and 6 on the final panel...



This is the Neutral Point for the right wing panel. Performing Step 7, as before, finishes the process.



Hermann Zahlmann's Horten XV mod. W

Mr. Zahlmann's Horten XV mod. appeared in our January 1994 column. The Horten XV mod. W is a bit different, and we thought readers would appreciate seeing the various modifications which Mr. Zahlmann implemented in an effort to improve performance.

Mr. Zahlmann's major goals for the W version were identical to those of the original. The resulting sailplane was to be good looking, inexpensive to build, and easily transported. It of course had to be stable in flight, yet controllable, and capable of both thermal and slope flying. A simple radio installation was also a requirement. A performance improvement was expected to be derived from the use of winglets rather than the previous low aspect ratio fins.

On the Horten XV mod., low aspect ratio fins acted as wing fences and also served to separate the twisted and untwisted portions of the wing. This was of great benefit, as the twisted portion of the wing utilized an inverted section, and the mating of two such dissimilar surfaces would have otherwise caused quite a large amount of interference drag. The W version uses winglets rather than low aspect ratio fins, but retains the use of an inverted section over the twisted portion of the wing. The mating of the untwisted and twisted portions of the wing presented a challenge, as some type of transition had to be designed. Mr. Zahlmann's solution incorporates a trailing edge "ramp" which we will describe later and which is detailed in the included 3-view.

As usual, Mr. Zahlmann included a few interesting construction methods in the building of the Horten XV mod. W:

• The entire wing is built on a flat surface. This is easily accomplished due to the use of the Clark Y section across most of the span. The section is inverted over the entire twisted portion of the wing, and jig blocks are used to assure proper alignment. Three degrees of dihedral, as measured at the bottom of the wing, is incorporated during the final stages of the construction process.

• The transition from untwisted to twisted portions of the wing is accomplished by means of a "ramp" in the trailing edge. This "ramp" crosses one bay, and when viewed from the rear rises at a 30 degree angle. The trailing edge of the wing is flush with the building surface from the root to the end of the untwisted portion, and raised a constant 35mm over the twisted portion.

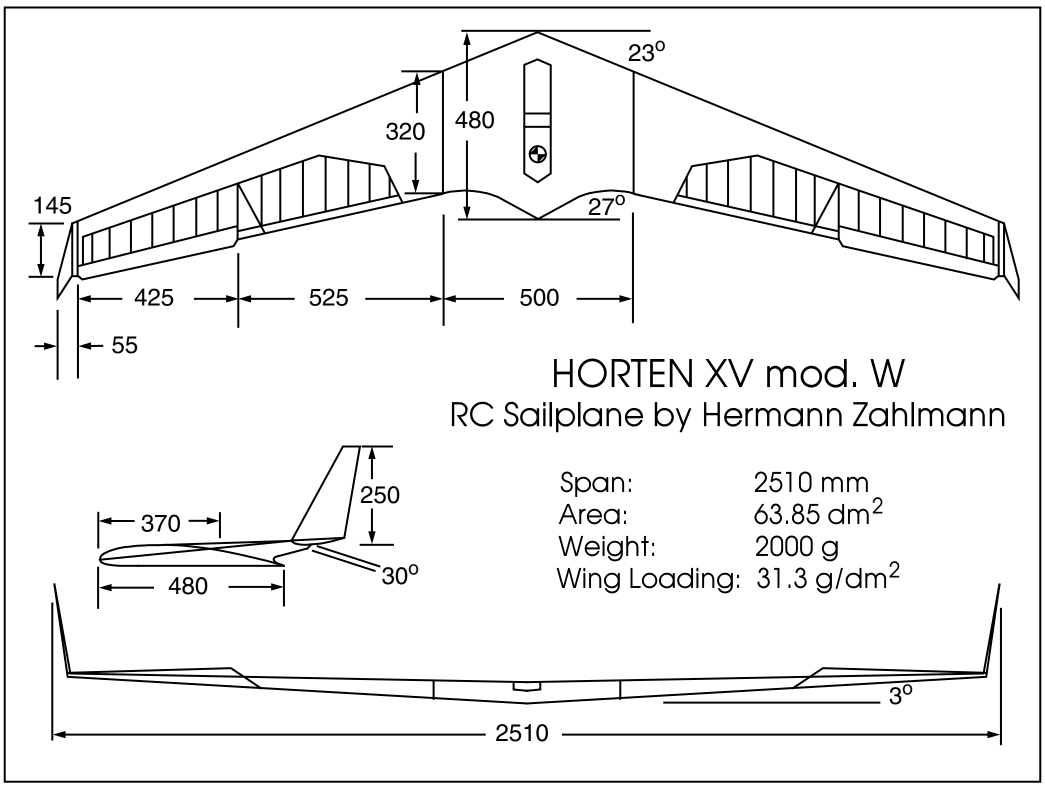
• The winglets are of relatively high aspect ratio and are angled outward ten degrees from the vertical plane. There is no toe-in; the winglets are aligned with the oncoming free stream flow.

• The W version, as the earlier model, has a cuspidate (bat) tail, but there is no reflex in the root section as used on the previous model.

The W version has a span of just over 2.5 meters, just slightly larger than the 2.4 meters of the previous, but the structure is essentially the same open wood frame and D-tube construction with fabric covering. The center section is large, and certainly capable of holding ballast when needed. Two servos are installed in the wing and drive the elevons directly. Flight characteristics are very similar to those exhibited by conventional tailed sailplanes. It has been flown repeatedly at the Wasserkuppe, in both strong and weak winds, with no problems. Thermal flying of the Horten XV mod. W is accomplished via a V-line and dual tow hooks.

The Horten XV mod. W demonstrates superior performance, has fulfilled all of Mr. Zahlmann's stated design goals, and offers an innovative wing junction which is worthy of study.

DELTA #2, Vereinsmagazin des FSV Versmold e.V. Reinhard H. Werner, editor. Halle/Westfallen Germany: FSV Versmold e.V., February 1986.



“Six-flap” Control Systems

In response to requests, here’s an examination of multiple control surface systems. These are commonly called “six-flap systems” in the literature, although, as you’ll see, some may have more than or less than six control surfaces in total.

The usual reason for a multiple control surface system is to more closely approximate the ideal lift distribution for all conditions, including maneuvers. Since a thermal sailplane is very seldom flying straight and level at a moderate speed, maintaining an appropriate lift distribution during other flight regimes has become a very important consideration. With modern computerized radios, it is possible to configure the transmitter such that control surfaces can be automatically adjusted to proper deflection without direct input from the pilot.

To begin, we’ll look at the control system used on the SB13 “Arcus,” the full sized swept wing sailplane built by Akaflieg Braunschweig and detailed in this column. This control system, depicted in Figures 1.1 and 1.2, uses elevator and aileron functions, along with differential rudders. The SB13 follows the Standard Class rules and therefore does not employ flaps.

The elevator function utilizes the outboard surfaces to produce a very strong force at the greatest possible distance from the CG. The movement of the inboard surfaces acts to distribute the aerodynamic load across a larger portion of the wing, thus reducing any stress rise.

As can be seen by Figure 1.2, aileron function involves some complex mixing of the control surface linkages. The aim here is to produce equivalent but opposite roll forces on the two wings, while at the same time reducing adverse yaw. This allows a rolling movement without the influence of either pitch or yaw forces. In a turn, the pilot can induce roll and pitch independently of rudder induced yaw.

The rudders are set up for differential movement. The outer rudder moves inward, albeit a very small amount, thus lifting it forward. The inner rudder, on the other hand, moves toward the center of the turn a great deal, creating a significant drag differential which slows the inner wing. Combined with appropriate pitch and roll inputs, the pilot is thus capable of making very efficient coordinated turns.

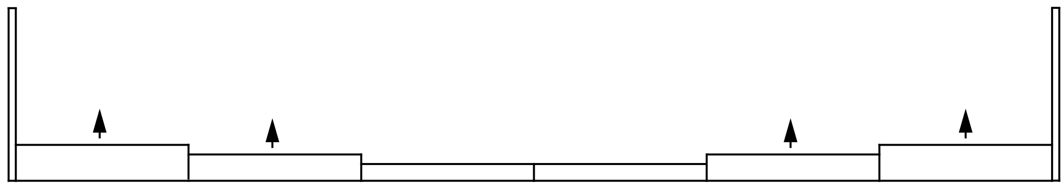


Figure 1.1: up elevator

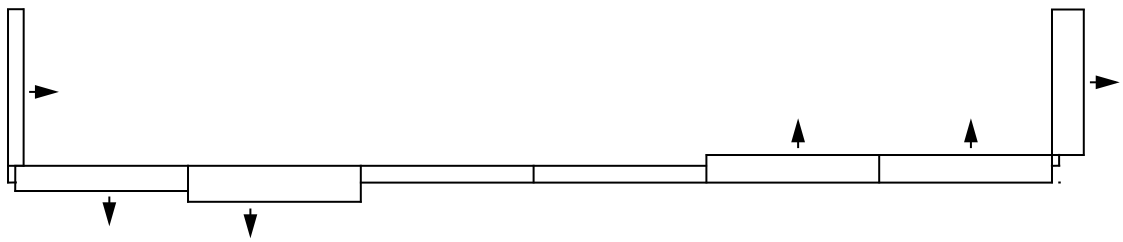


Figure 1.2: right aileron with right rudder

Akaflieg Braunscheig’s SB13 “Arcus”

The next two systems we’ll look at have been used by Dr. Michael Wohlfahrt. Dr. Wohlfahrt is co-author, with Dr. Karl Nickel, of “Schwanzlose Flugzeuge,” a very extensive and complete book on tailless aircraft, with sailplanes the primary focus. The two control systems described here (Figures 2.1- 2.4 and Figures 3.1-3.4) were published about a year apart, with the latter system being the most recent.

These two systems are roughly equivalent, with the exception of aileron function and a small difference in deflection angles in landing mode. It would appear aileron function was changed from a rather complex mixing configuration, similar to that seen on the SB13, to one which is more simple and seems to derive added effectiveness from increased leverage.
We’ve kept the most complicated control system for last. DELTA #4 provided information on Hansjorg Ackerman’s SWALC (Swept Wing Automatic Lift Control). This control system, which uses Multiplex equipment with a “Softmodul,” allows inclusion of some rather unique control functions and is illustrated in Figures 4.1- 4.5.

It is interesting to note the SWALC elevator function, as it is directly opposite to what is seen in the SB13. Mr. Ackerman’s intent is to promote a very specific lift distribution over the outer wing. Since the wing incorporates washout, and produces a “bell shaped” lift distribution when no control surfaces are deflected, elevator function must overcome that initial lift distribution and produce a lift distribution which is most effective at giving

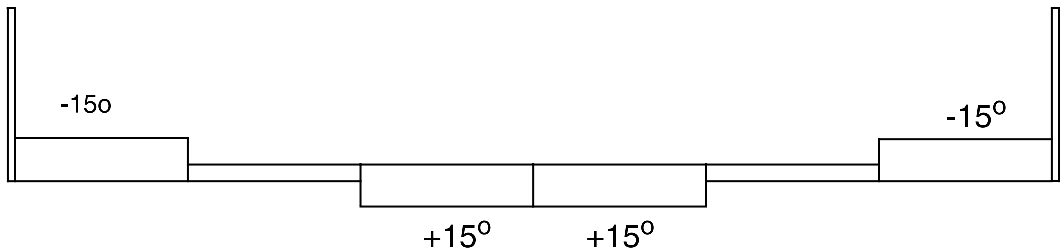


Figure 2.1: up elevator

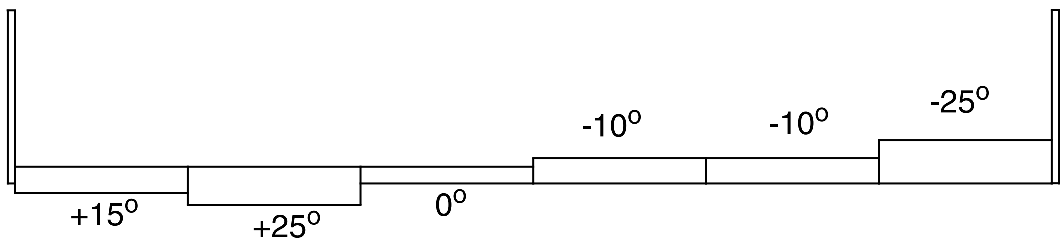


Figure 2.2: right aileron

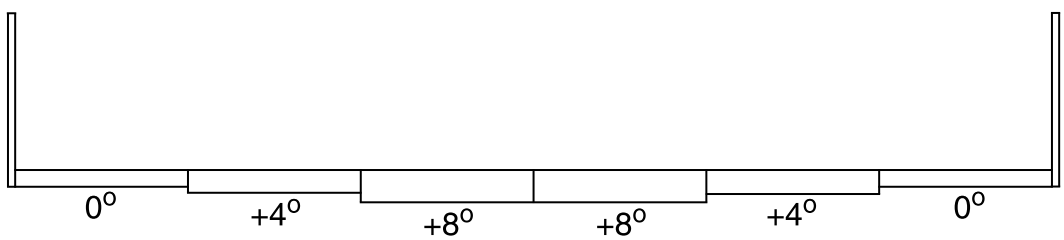


Figure 2.3: positive flap

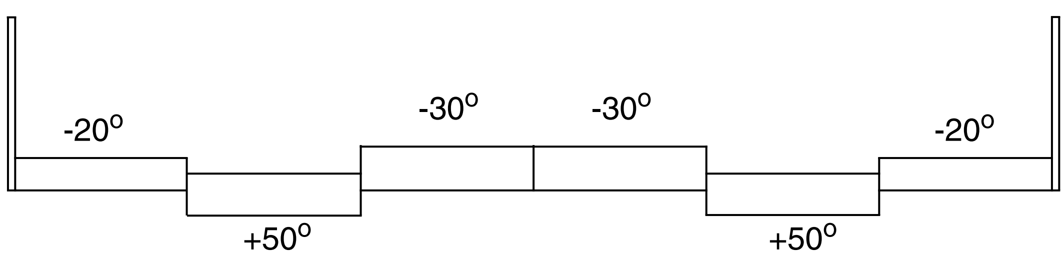


Figure 2.4: landing

Dr. Michael Wohlfahrt, 1989

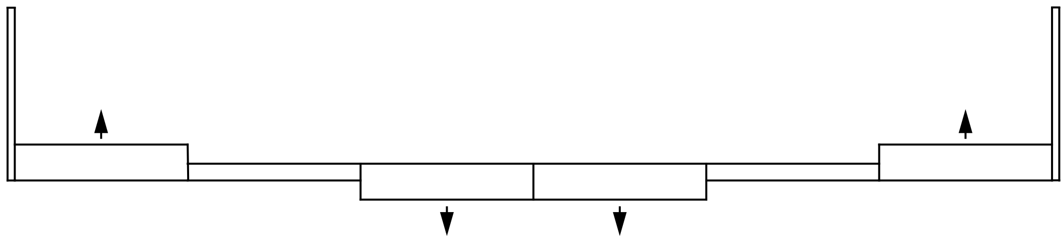


Figure 3.1: up elevator

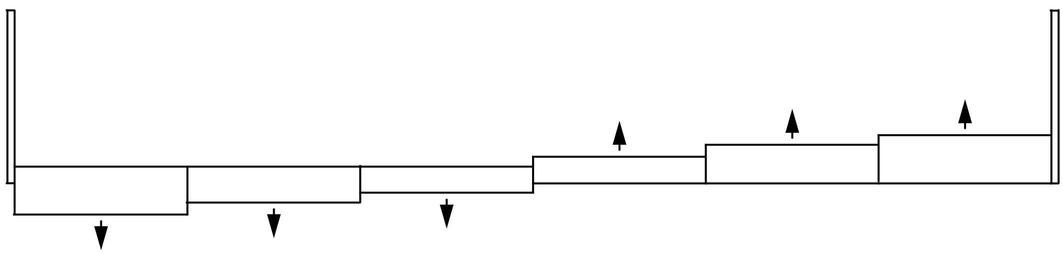


Figure 3.2: right aileron

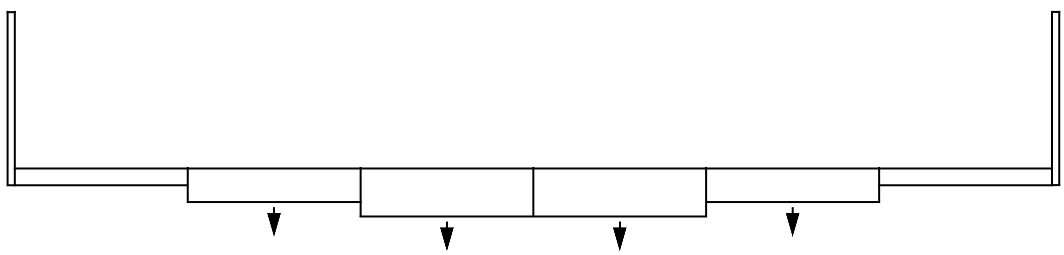


Figure 3.3: positive flap

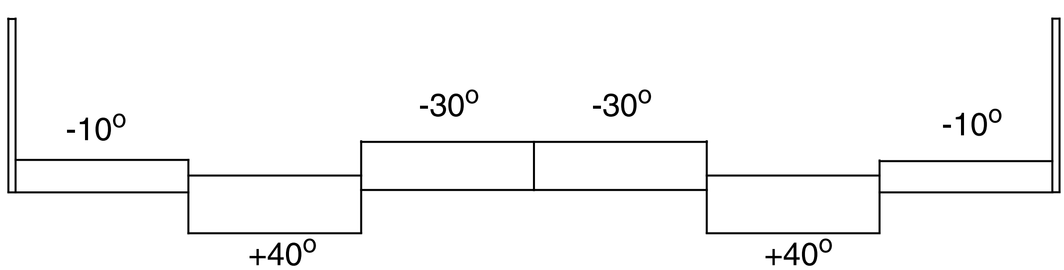


Figure 3.4: landing

Dr. Michael Wohlfahrt, 1990

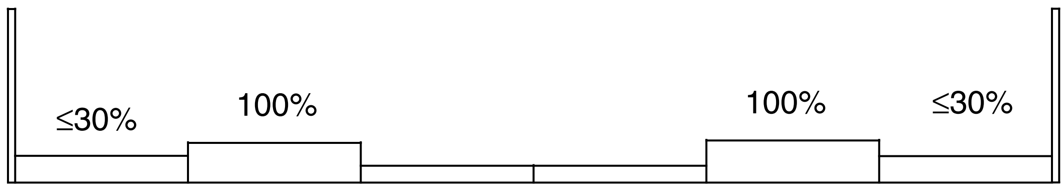


Figure 4.1: up elevator

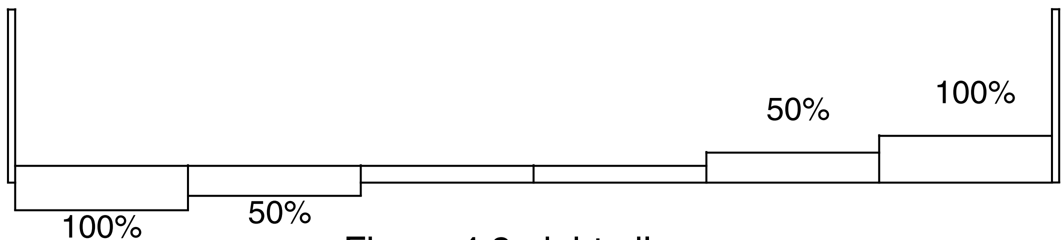


Figure 4.2: right aileron

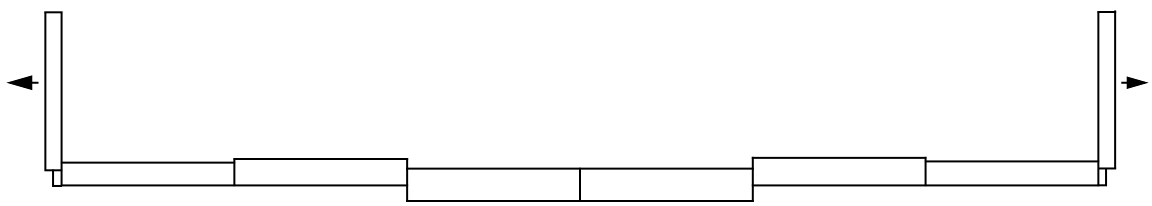


Figure 4.3: thermal

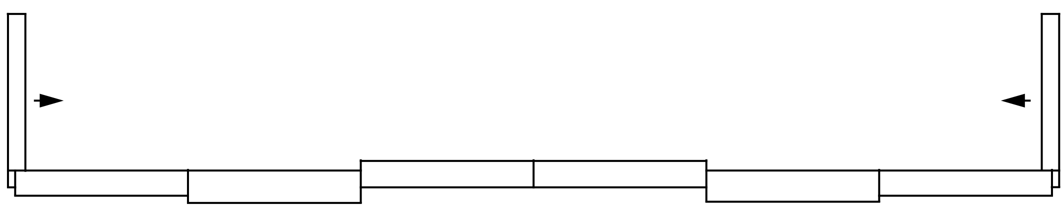


Figure 4.4: speed

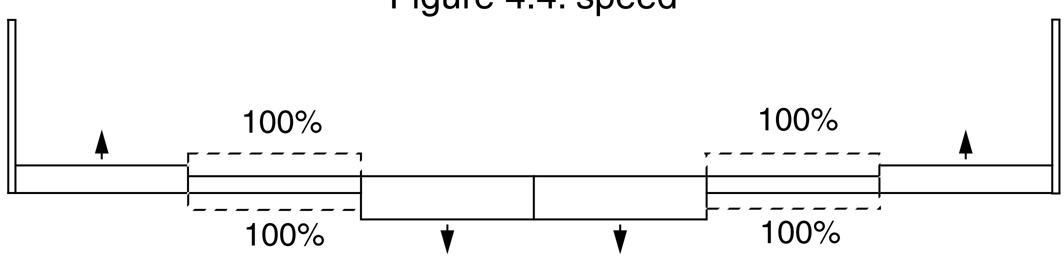


Figure 4.5: landing

Hansjorg Ackerman, S.W.A.L.C.

the pitch authority needed. Aileron function is unique in its own way as well, in that includes absolutely no differential. We have talked about swept wings and aileron differential previously, and Mr. Ackerman's control system adds credence to our contentions.

Rudders, if they can be called that, are not used in turning. However, they play a very important role in thermal and speed modes, where they trim the vertical surface to best advantage for a specific flight regime. In thermal mode, the rudder surfaces move outward, and the vertical fins become pseudo-winglets which contribute to improving lift. In speed mode, the rudder surfaces deflect slightly inward, reducing the drag of these surfaces to a minimum.

In landing mode, flaps go down and outboard control surfaces move up. This is a "butterfly" configuration, and the control surfaces move in relative unison. Pitch control in this configuration is accomplished by deflection of the middle control surfaces and should be very effective.

It should be noted that each of the described control systems is installed in a different wing planform, with sweep angle and taper ratio sometimes varying markedly between designs. Before incorporating any multiple control surface system into a design, great care needs to be taken to assure the lift distribution will be affected in the exact way the designer wishes.

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Modifying the Quality Fiberglass "Javelin"

Earlier this year we had a chance to talk to Steve Savoie of Gotham Maine. Steve had constructed a "Javelin" and was very pleased with its performance, despite a relatively high wing loading brought on by "overstrengthening." The "Javelin" is a true flying wing which is extremely easy to build. Balsa sheeted foam core wings and solid balsa elevons promote rapid construction of the basic airframe, while installation of radio gear entails only some hatch cutting and a bit of foam removal.

Several members of the DownEast Soaring Club, Steve's flying group, expressed interest in modifying the "Javelin" for the specific purpose of improving its performance on the slope, and Steve contacted us for advice. Here are a couple of questions which Steve relayed to us.

Carl Trottier: *"Since the wing has no twist (washout) and is designed to fly in level flight with the elevons reflexed 1/8", can I transpose the reflex into washout and fly on the slope without reflexing the elevons and thereby producing less drag with a cleaner wing?"*

The "Javelin" planform, depicted in Figure 1a, incorporates several features designed to make construction easy and set-up simple, but there are necessary compromises in other areas.

The "Javelin" elevon reflex produces a down force which provides the positive pitching moment necessary for stability, but does so across nearly the entire span. Reflexing the root airfoil is not necessary and is probably detrimental to overall performance. The "Javelin" quarter chord line is swept back 22 degrees, so twisting the wing (washout) would be more efficient.

Figure 2a shows the original geometry of the "Javelin" wing at the end of the elevon; Figure 2b shows the same section's geometry when the elevon trim is replaced by an equivalent amount of wing twist. The twist value works out to be very close to 1.5 degrees, as noted on the drawing. This is a reasonable amount of wing twist, and could be easily incorporated into the wing during construction, particularly if custom cores were made. The Panknin formulae indicate this is the amount of twist to used for a design C_L of 0.25 with a static margin of 0.02; these are average values for a responsive aircraft designed for slope flying.

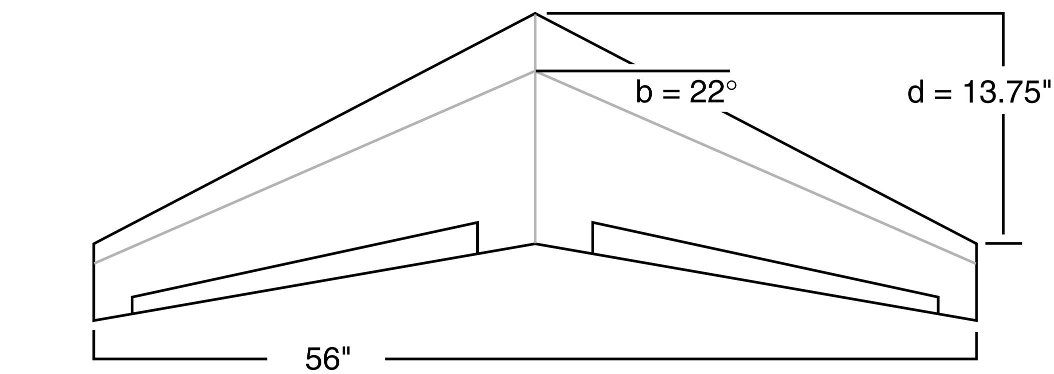


Figure 1a

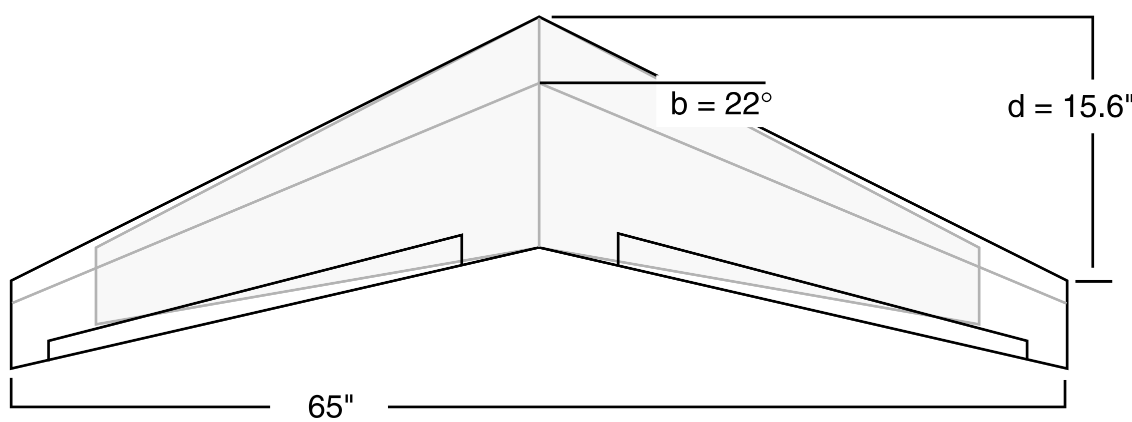


Figure 1b

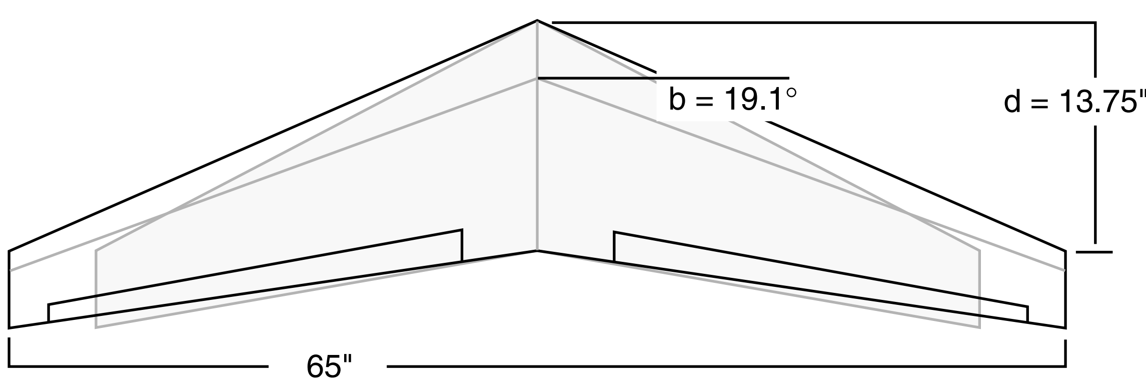
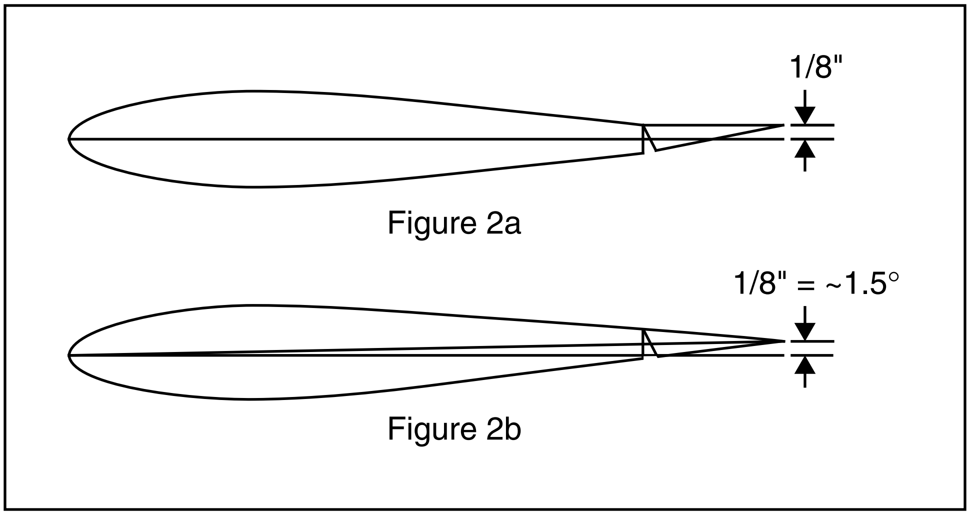


Figure 1c



The original "Javelin" uses a symmetrical section without twist, so inverted flight is simply a matter of reversing elevon trim. Exchanging wing twist for elevon trim makes sustained inverted flight more difficult, as the required down elevon trim will be significantly greater. Using twist instead of elevon reflex may reduce overall drag in normal flight, but there will be a substantial increase in drag during sustained inverted flight.

Walter Mudget: *"Can I keep the original 15" root and 5" tip chords and increase the wingspan from 56" to 65"?"*

Adding a few inches to the "Javelin" span increases the aspect ratio, and the larger size will make it easier to see. There are two ways of increasing the wing span: keep the sweep angle, β, constant as shown in Figure 1b, or keep the sweep distance, d, constant as shown in Figure 1c. As can be seen in the accompanying Table, the wing twist values remain very close to that established for the original 56" span, regardless of which of the two methods is used to increase the wingspan.

Here are some other possible modifications which can improve the "Javelin" performance:

- As we said earlier, the size and location of the elevons could be improved. Their span should be reduced and chord enlarged, and the area concentrated in the outboard portions of the wing panels. See Figure 3.

- For those interested in flying the "Javelin" in light lift, a measurable increase in performance can be obtained through the use of a cambered wing section. We chose two of the EH series of airfoils for inclusion in the Table. The EH sections have low drag values and extremely low pitching

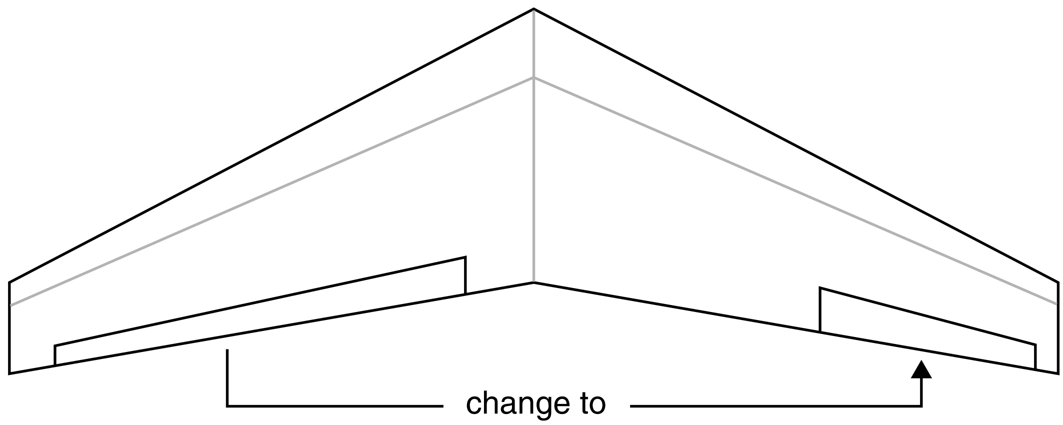


Figure 3

Span	AR	Sweep Angle, b	Area	Wing Loading*	Airfoil	Req'd Twist‡
56"	5.6	22	560	7.5 oz/ft^2	Symmetrical	-1.38°
					EH 1.0/9.0	-1.24°
					EH 2.0/10.0	-1.19°
65"	6.5	22	650	6.4 oz/ft^2	Symmetrical	-1.12°
					EH 1.0/9.0	-1.00°
					EH 2.0/10.0	-0.96°
65"	6.5	19.1	650	6.4 oz/ft^2	Symmetrical	-1.29°
					EH 1.0/9.0	-1.16°
					EH 2.0/10.0	-1.11°

* based on a total flying weight of 29 ounces
‡ based on a design C_L of 0.25 and a stability factor (static margin) of 0.02

moments, yet are capable of very high lift. These attributes make them very attractive choices.

- The “Javelin” airfoil is almost 12.5% thick. While this gives a large amount of room for radio gear, using a thinner wing section will cut drag and produce a slightly lighter airframe. A section with 7.0% thickness, for example, provides over an inch of height at the “Javelin” 15 inch root. There is sufficient volume for one of the new slim-line receivers and a flat battery pack, and the outer portions of the wing remain thick enough to house small servos for direct drive to the elevons. Coordinates for thinned renditions of any section can be obtained quite easily with some of the available airfoil plotting programs. This opens some intriguing possibilities for those interested in 60" slope racing.

The “Javelin” planform provides a good basis for experimentation, and readers interested in making modifications for improved performance have several options open to them in addition to those mentioned above.

A scene from the First Japan National RC-HLG contest.
Photo courtesy of Paul Clark.

Dr. Martin Lichte's EMX 07 and EMX 14

Dr. Martin Lichte's EMX 07 was originally featured in this column in December of 1988, along with his Phoenix and Elina profiles. Since the coordinate table for the EMX 07 given at that time contained only 36 points, we thought it time for enhanced plotting information. When we wrote that original article, aerodynamic data for this section was not available; the included table lists all of the relevent information.

Also covered this month is one of Dr. Lichte's newer sections, the EMX 14. This section is a bit thicker than the EMX 07, and has a lower pitching moment. Aerodynamic data for the EMX 14 is also included in the accompanying table.

It should be noted the EMX 07 was originally recommended for use on wings with a small amount of sweepback (about 10°), rather than planks. Our own recent experience, however, has shown plank planforms do not need large amounts of reflex and high positive pitching moments. We would not hesitate to use the EMX 07 on a high performance plank planform.

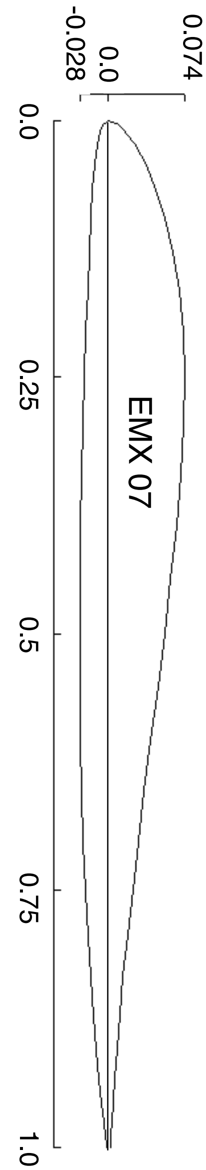
The EMX 14, on the other hand, with a pitching moment near zero, should be used on moderately swept wings. If you choose to use the EMX 14, utilize the Panknin computer program to assure your design has sufficient stability.

AERODYNAMIC DATA

	EMX 07	EMX 14
thickness	9.91%	10.63%
$x_{max\ thickness}$	28.4	34.2
camber	2.54%	1.82%
$x_{max\ camber}$	22.8	34.5
$\alpha_{zero\ lift}$	-0.30º	-0.50º
c_m	0.0210	0.0019

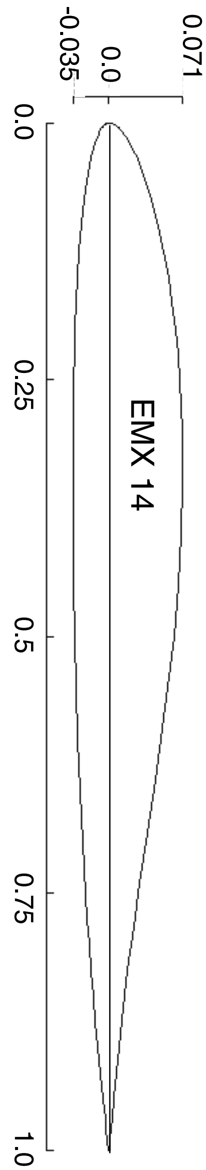
EMX 07

XU	YU	XL	YL
0.000	0.000	0.000	0.000
0.274	0.723	0.274	-0.495
1.093	1.679	1.093	-0.831
2.447	2.692	2.447	-1.113
4.323	3.690	4.323	-1.362
6.699	4.655	6.699	-1.571
9.549	5.555	9.549	-1.751
12.843	6.333	12.843	-1.916
16.543	6.921	16.543	-2.077
20.611	7.291	20.611	-2.236
25.000	7.447	25.000	-2.394
29.663	7.360	29.663	-2.539
34.549	7.074	34.549	-2.656
39.604	6.636	39.604	-2.744
44.774	6.091	44.774	-2.801
50.000	5.475	50.000	-2.825
55.226	4.819	55.226	-2.811
60.396	4.152	60.396	-2.756
65.451	3.504	65.451	-2.659
70.337	2.896	70.337	-2.502
75.000	2.339	75.000	-2.273
79.389	1.845	79.389	-2.013
83.457	1.425	83.457	-1.755
87.157	1.078	87.157	-1.497
90.451	0.793	90.451	-1.225
93.301	0.571	93.301	-0.947
95.677	0.407	95.677	-0.688
97.553	0.291	97.553	-0.466
98.907	0.152	98.907	-0.295
99.726	0.152	99.726	-0.189
100.000	0.152	100.000	-0.152



EMX 14

XU	YU	XL	YL
0.000	0.000	0.000	0.000
0.050	0.258	0.050	-0.231
0.101	0.374	0.101	-0.319
0.151	0.466	0.149	-0.385
0.201	0.546	0.199	-0.438
0.251	0.618	0.249	-0.485
0.301	0.684	0.299	-0.526
0.401	0.803	0.399	-0.600
0.501	0.910	0.499	-0.664
0.752	1.146	0.749	-0.799
1.002	1.351	0.999	-0.915
1.252	1.535	1.249	-1.022
1.502	1.705	1.498	-1.121
2.003	2.010	1.998	-1.303
2.503	2.280	2.498	-1.464
3.504	2.755	3.497	-1.732
5.005	3.348	4.997	-2.040
7.506	4.142	7.496	-2.423
10.007	4.778	9.996	-2.702
12.508	5.302	12.496	-2.913
15.008	5.737	14.996	-3.075
17.509	6.100	17.495	-3.201
20.009	6.403	19.995	-3.298
22.510	6.650	22.495	-3.372
25.010	6.844	24.995	-3.425
27.510	6.989	27.495	-3.462
30.010	7.084	29.995	-3.484
35.010	7.132	34.995	-3.491
40.010	6.998	39.995	-3.457
45.010	6.693	44.995	-3.390
50.009	6.245	49.995	-3.290
55.008	5.684	54.995	-3.159
60.007	5.035	59.996	-2.996
65.006	4.327	64.996	-2.796
67.506	3.958	67.496	-2.681
70.005	3.587	69.996	-2.555
72.505	3.214	72.496	-2.419
75.004	2.845	74.997	-2.270
77.504	2.484	77.497	-2.110
80.003	2.132	79.997	-1.936
82.503	1.795	82.497	-1.747
85.002	1.476	84.998	-1.544
87.502	1.179	87.498	-1.327
90.001	0.910	89.998	-1.094
92.501	0.668	92.499	-0.847
95.001	0.449	94.999	-0.588
97.000	0.285	96.999	-0.375
98.000	0.206	98.000	-0.267
99.000	0.127	99.000	-0.159
100.000	0.050	100.000	-0.050



The great bird will take its first flight...
filling the world with amazement and all records with its fame,
and it will bring eternal glory to the nest where it was born.

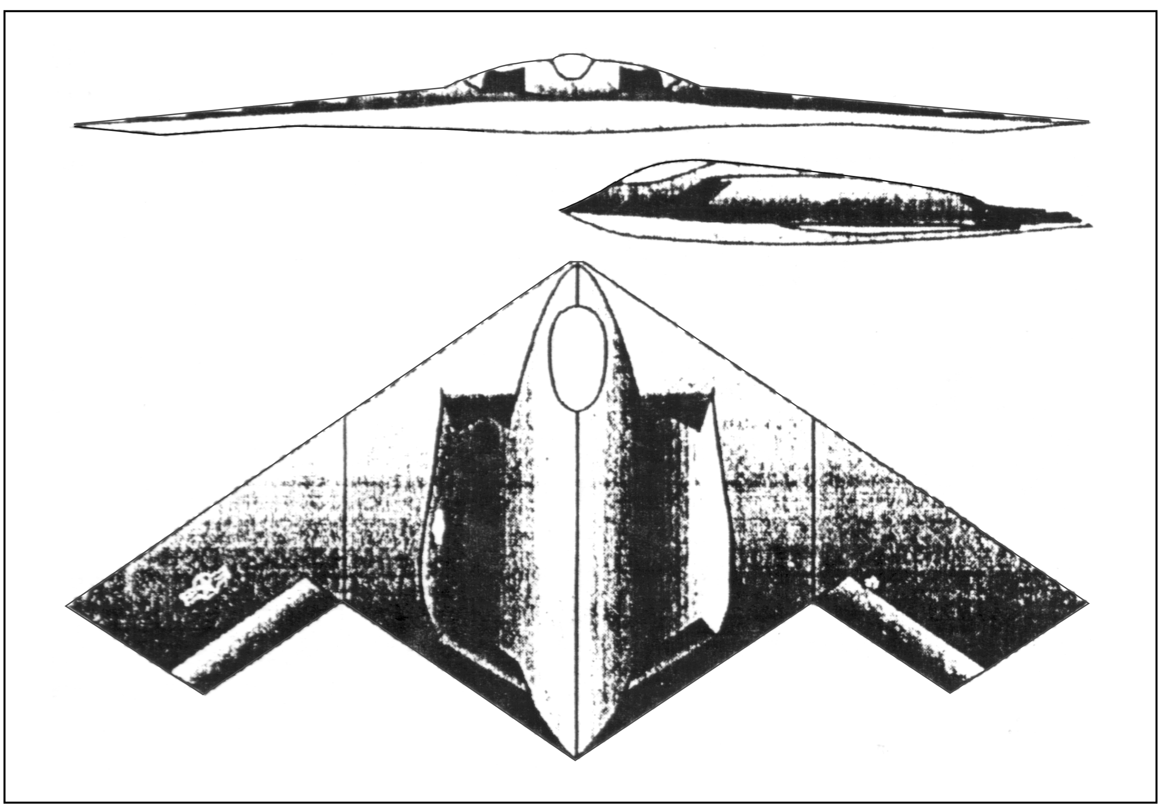
— Leonardo da Vinci

The Newest Stealth Fighter a candidate for P.S.S.?

Issue number 95 of *The T.W.I.T.T. Newsletter* (May 1994) featured a story on what is reported to be the newest stealth fighter, complete with 3-view plans! The story came from the Associated Press, and was submitted to T.W.I.T.T. by Fred Blanton who found it in his local newspaper.

Jane's International Defense Review in March of 1994 published a drawing of an aircraft which had been several times seen in flight in the southwest, particularly around Groom Lake Air Force Base in Nevada. As is usual with such aircraft, the Air Force did not comment either positively or negatively about the existence of this unidentified plane. However, as there are at least two videotapes of this aircraft in flight, it would appear PSS fans have a new subject to model.

As can be seen from the accompanying 3-view, the new aircraft resembles the B-2 stealth bomber in many ways. The author of the report, Bill



Sweetman, is a well known aviation writer. He believes it to be the successor to the F-117 stealth fighter, and superior to it in several ways; greater range, increased weapons capability, and even better stealth technology.

Clifford Beal, the journal’s features editor, viewed the videotapes and reports the plane flies at low to medium altitudes and appears to be capable of over 500 mph.

The fact that this newest stealth fighter has a lot of potential as a slope ’ship was of course left out of the AP news story.

Dimensions for the full size aircraft are not available at this time. We suggest making a model as large as possible while maintaining all dimensions directly proportional to the plans included here. When the dimensions of the original are available, the actual scale can then be computed.

"The Middle Effect"

In the March 1994 issue of *RCSD*, we discussed Dr. Ing. Ferdinando Galè's Ubara, a swept wing free flight HLG. This model featured a "bat tail," and a good portion of our column was devoted to an examination of possible effects this configuration might have on performance. Figure 1, which was included in that column, generated the following request from Ted Off, of Ventura California:

"That little 'throw away' drawing of the Horten brothers (p. 14, *R/C Soaring Digest*, 3/94) was fascinating. I've never seen this idea before. How about more information in your next column?"

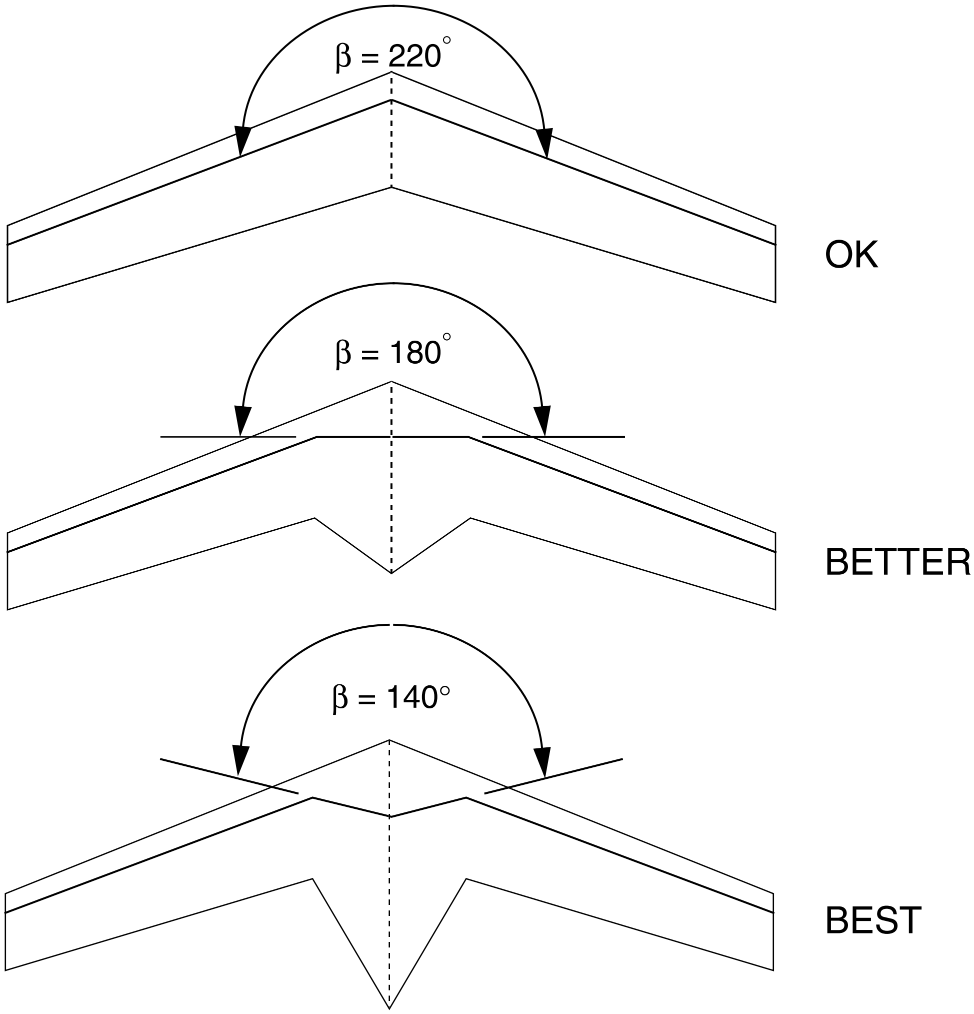
Well, we didn't get his written in time for the next column. In fact, we're well into the next year! Hopefully, however, this month's column will provide the information Ted was requesting.

The "bat tail" or "cuspidate tail," as it is also known, has been portrayed as a method of compensating for "the middle effect," defined as a loss of lift at the center of a swept wing.

The proposed reason for this loss of lift is the detrimental interaction of vortices at the center of the wing. The Horten brothers offered a solution to this problem: construct the wing such that the quarter chord lines of the two wing halves meet at an angle of less than 180° at the center line. Refer to Figure 1 to see how this is accomplished. This modification of the quarter chord line is said to change the angle at which the vortices meet, thus inhibiting the adverse action. A side effect of this is an increase in the wing area at the root which gives a proportional increase in lift.

A logical question to be asked is, "How did designers and pilots recognize such a loss of lift at the center section?" The answer is, through flight experience. It was found that even though the CG had been determined by calculating the lift distribution, the resulting aircraft was always nose heavy in flight. To explain this nose heaviness, it was assumed there was a loss of lift at the center of the wing.

Such an aerodynamic explanation turns out to be not correct, however. To find the real reason for the nose heaviness of sweptback wings, it is only

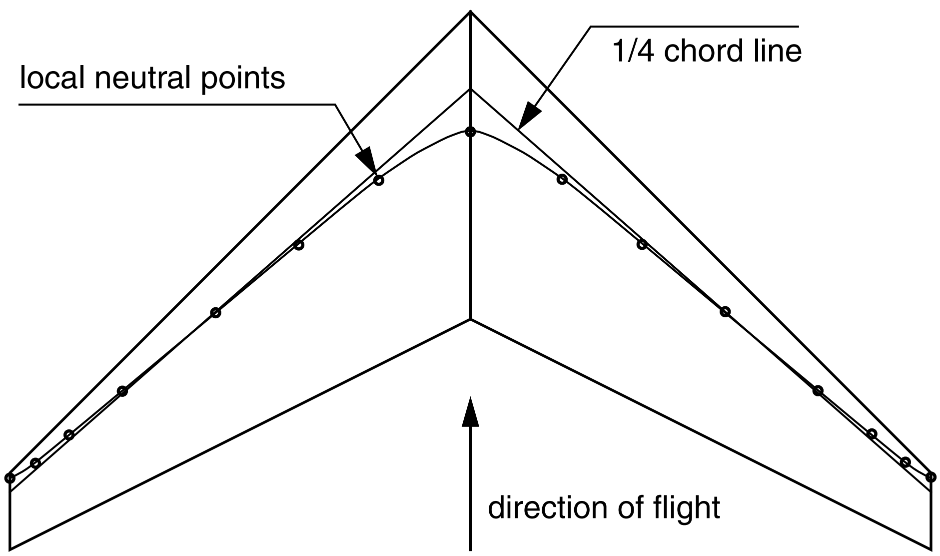


β, the angle at which the quarter chord lines of the two wings meet at the center line, should be less than 180°, according to the Horten brothers.

Figure 1

necessary to look at the method being used for determining the lift distribution.

Figure 2 shows that for a swept back wing, the lines formed by the local neutral points do not follow the quarter chord lines. The local neutral point is aft of the quarter chord line at the center line, and ahead of the quarter



Local neutral point behind quarter chord line at root,
ahead of quarter chord line at tip.

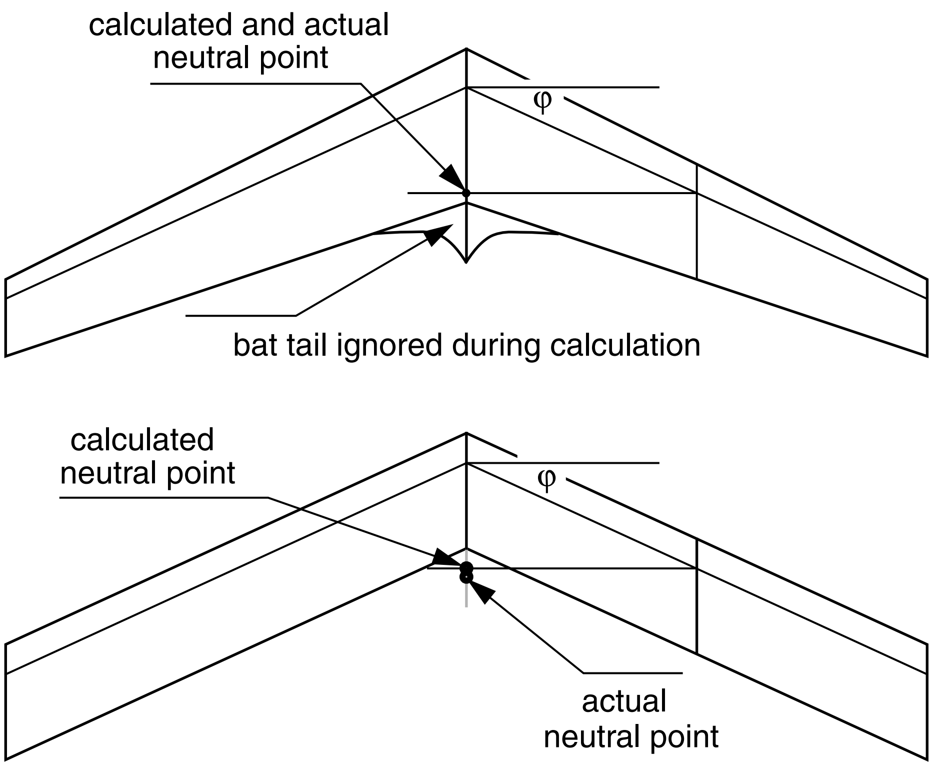
Figure 2

chord line at the wing tip. This is the case for all wings which are swept back. (If the wing is swept forward, the situation is reversed.)

Prior to and during World War II, the lift distribution of swept wings was determined by working out the lift distribution of an "equivalent" unswept wing. That lift distribution was then placed on the quarter chord line of the swept wing. This led to errors, but until about 1950 there was no better way.

This method of calculating the lift distribution predicted too much lift for the center of the wing and too little for the wing tips. The calculated neutral point of the aircraft was therefore forward of the actual location. Since the location of the CG is based on the location of the neutral point, it also was excessively forward, thus leading to a nose heavy condition.

The nose heaviness experienced in flight, then, was not due to any true loss of lift, but rather to errors in the calculation of the neutral point; an aerodynamic phenomenon was erroneously blamed for what was really a mathematical shortcoming. Modern full size swept wing aircraft are designed using computational fluid dynamic methods which can predict the effects of



Sweep angle, φ, as measured at the quarter chord line, is identical in both cases.

Panknin formulae used to determine the location of neutral point.

Figure 3

sweep on the location of the neutral point and so the CG is placed accurately.

We’ll complete this month’s column with an interesting sidenote.

Our good friend Alan Halleck has been designing and building swept wings for thermal and slope flight for a number of years. His Razer1, an extremely successful design, appeared in this column in May 1991. Alan uses the Panknin formulae to determine both wing twist and CG location. As a reminder, the Panknin formulae determines the location of the CG based upon the (arithmetic) mean quarter chord point and a prescribed stability factor. All of Alan’s ’wings are of tapered planform and incorporate a bat tail formed by a proportionally enlarged root section. The bat tail is ignored during computations, yet all of Alan's designs have flown exceedingly well using the CG location determined by the Panknin formulae. In fact, he has consistently found movement of the CG away from the specified location leads to poorer performance.

In direct contrast to this experience, our own swept 'wings, which are of constant chord and do not incorporate a bat tail, have always proven to be slightly nose heavy when balanced according to the Panknin formulae.

Reference:

Nickel, Karl and Michael Wohlfahrt. Tailless Aircraft in Theory and Practice. American Institute of Aeronautics and Astronautics, Washington D.C., 1994. pp. 445 - 447.

Winglets forever!

— Hans-Jürgen Unverferth

The EH 0.0/9.0

The EH 0.0/9.0 is another in a series of sections designed by John Yost; it has no camber and is 9% thick. As a symmetrical section it has a pitching moment of zero and a relatively limited maximum lift coefficient. For enthusiasts of tailless planforms, however, the EH 0.0/9.0 has at least two useful functions. The EH 0.0/9.0 can be used as the section of choice for vertical stabilizers, whether as “winglets” or as a single central fin. It can also be used in a more fundamental role as a thickness distribution in conjunction with a predetermined camber line.

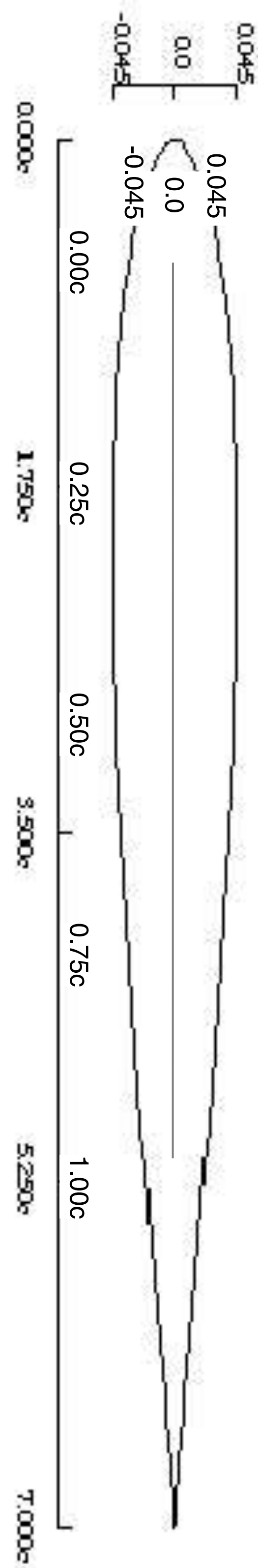
As a vertical surface section, the EH 0.0/9.0 may be considered by some to be somewhat thick. However, as other of the EH sections have been thinned successfully, there should be no major concern over thinning this section as well. Such thinning should be done in moderation; 7% should be the minimum thickness considered.

If the EH 0.0/9.0 is used to place a thickness distribution around a camber line, we would highly recommend using the algebraic rather than the trigonometric method. The trigonometric method involves adding the thickness distribution along an artificial axis which is perpendicular to the local camber line, while the algebraic method always adds the thickness distribution parallel to the Y axis. The algebraic method is far easier to accomplish and gives a leading edge shape which seems to provide better stall characteristics.

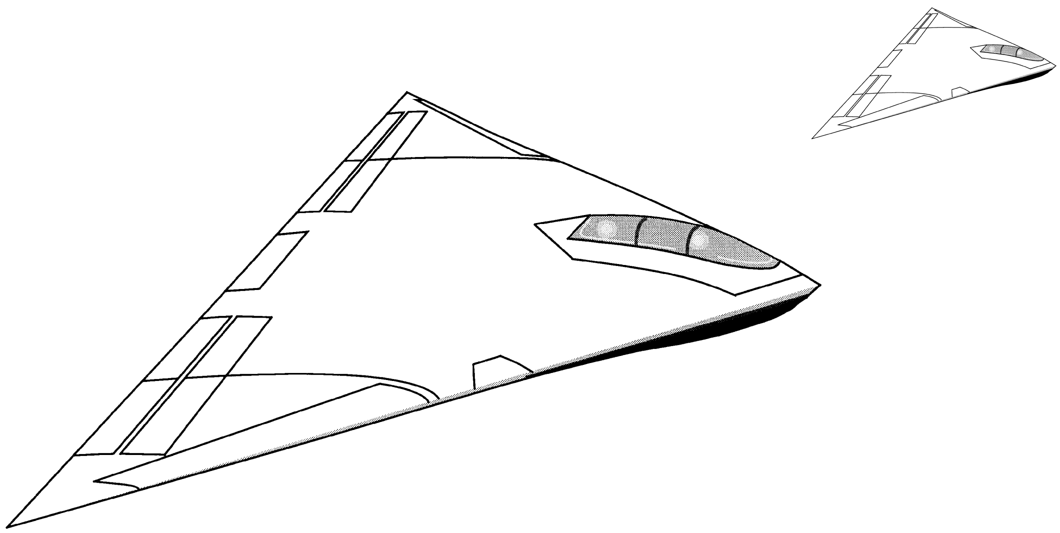
For those of you who wish to use camber lines appropriate for plank planforms, see “On the ’Wing…,” *RC Soaring Digest*, June 1990. That column provides the formulae for camber lines with various crossover points. If you do not have that specific back issue of *RCSD*, the column is reprinted in “On the ’Wing… the book,” published by our own B^{2}Streamlines. The reprint also includes a computer program which calculates various reflexed camber lines and then imposes a chosen thickness distribution.

EH 0.0/9.0

X	Y	X	Y
100.000	0.000	0.099	-0.289
99.901	0.004	0.394	-0.623
99.606	0.018	0.886	-0.984
99.114	0.046	1.571	-1.350
98.429	0.092	2.447	-1.726
97.553	0.158	3.511	-2.094
96.489	0.243	4.759	-2.445
95.241	0.345	6.185	-2.778
93.815	0.463	7.784	-3.087
92.216	0.597	9.549	-3.370
90.451	0.748	11.474	-3.624
88.526	0.916	13.552	-3.847
86.448	1.100	15.733	-4.039
84.227	1.297	18.129	-4.198
81.871	1.505	20.611	-4.323
79.389	1.724	23.209	-4.415
76.791	1.950	25.912	-4.474
74.088	2.181	28.711	-4.500
71.289	2.415	31.594	-4.495
68.406	2.648	34.549	-4.460
62.435	3.104	37.565	-4.396
59.369	3.320	40.631	-4.306
56.267	3.526	43.733	-4.191
53.139	3.716	46.961	-4.054
50.000	3.895	50.000	-3.895
46.961	4.054	53.139	-3.716
43.733	4.191	56.267	-3.526
40.631	4.306	59.369	-3.320
37.565	4.396	62.435	-3.104
34.549	4.460	68.406	-2.648
31.594	4.495	71.289	-2.415
28.711	4.500	74.088	-2.181
25.912	4.474	76.791	-1.950
23.209	4.415	79.389	-1.724
20.611	4.323	81.871	-1.505
18.129	4.198	84.227	-1.297
15.733	4.039	86.448	-1.100
13.552	3.847	88.526	-0.916
11.474	3.624	90.451	-0.748
9.549	3.370	92.216	-0.597
7.784	3.087	93.815	-0.463
6.185	2.778	95.241	-0.345
4.759	2.445	96.489	-0.243
3.511	2.094	97.553	-0.158
2.447	1.726	98.429	-0.092
1.571	1.350	99.114	-0.046
0.886	0.984	99.606	-0.018
0.394	0.623	99.901	-0.004
0.099	0.289	100.000	0.000
0.000	0.000		



A-12 “Avenger 2”/”Dorito”
yet another candidate for P.S.S.?

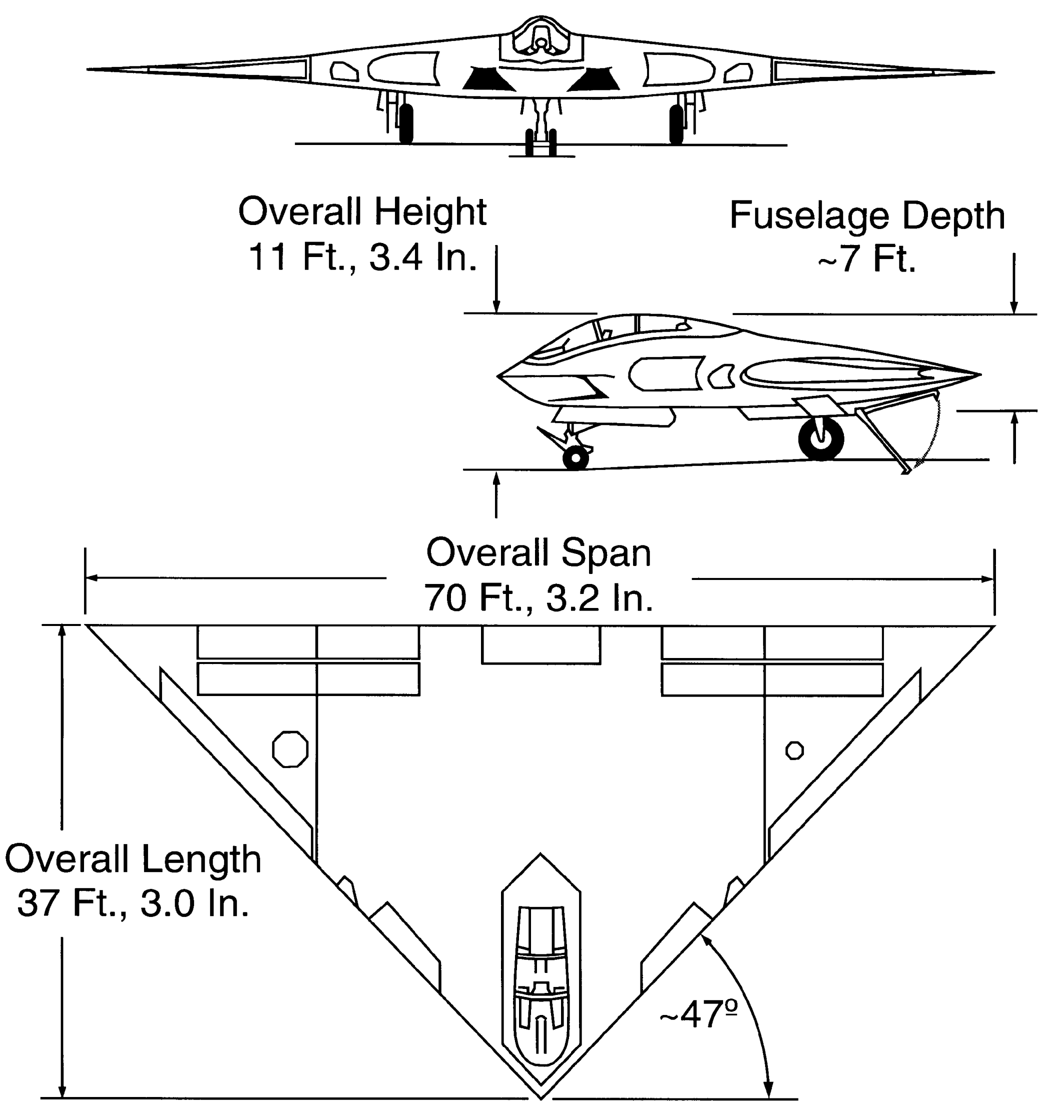


Here’s a challenge to you power scale slope enthusiasts — the A-12 “Avenger,” also known as the “Dorito.”

The A-12 was designed for use by the U.S. Navy, and was to be built by General Dynamics and McDonnell Douglas for carrier operations as a replacement for the A-6 “Intruder.” First flights were scheduled for 1992, with sea trials in 1993, crew training in 1994, and entry into operational status in 1995. According to initial plans, 858 aircraft were to be built. The entire project was cancelled in 1991, however, for economic reasons.

The A-12 is a true delta wing, and therefore has a relatively low aspect ratio. A light wing loading was expected to be mandatory for good landing characteristics. To give some idea as to how this translated into the actual aircraft, it should be noted the A-12, although about 20% heavier than the F-14A “Tomcat,” has more than double the wing area, while wetted area is about the same. Further comparison of the A-12 and F-14 may be made using the data within the included table.

The A-12 includes a central elevator for pitch trim (quite reminiscent of the system used on the Douglas F4D-1 “Skyray”), elevons for roll and pitch control, spoilers ahead of the elevons, and leading edge slats which have an aerodynamic effect over about a quarter of the wing area. The A-12 has no vertical surface. Elevons alone should provide sufficient pitch and roll



A-12 “Avenger”/”Dorito”

authority for a model, but some fin area may be necessary for directional stability, as the forward portion of the fuselage is relatively deep.

We’re eager to hear from any readers who tackle this project.

Information for this column was derived from:

“Stealthy Avenger.” *Popular Mechanics*, November 1990.

Angelucci, Enzo, and Peter Bowers. The American Fighter . Orion Books, New York, 1985.

Berliner, Don. “Dorito.” *Model Aviation*, April 1991.

Morrocco, John D. “Funding Cuts May Limit Carrier Air Wings to 16 A-12s.” *Aviation Week & Space Technology*, 01 October 1990.

Renshaw, Kevin. “A-12 Avenger Stealth Fighter.” *TWITT Newsletter* #113, November 1995.

Dimension	A-12 Avenger 2/Dorito	F-14A Tomcat
span	70 ft. 3.2 in.	64 ft. 1.5 in. max. 38 ft. 2.5 in. min.
length	37 ft. 3.0 in.	61ft 11.75 in.
height, ground to top of canopy	11 ft, 3.4 in.	12 ft.
fuselage thickness	~7 ft.	~7 ft.
aspect ratio, wing	3.75	7.2 max. 2.58 min.
wing area	1,308 ft.2	565 ft.2
gross weight	80,000 lbs.	66,200 lbs.
wing Loading	61 lbs./ft.2	117 lbs./ft.2
design load factor	9g	—
program status	cancelled 1991	~900 in service

*It is not because things are difficult that we do not dare,
it is because we do not dare that they are difficult.*

— Seneca

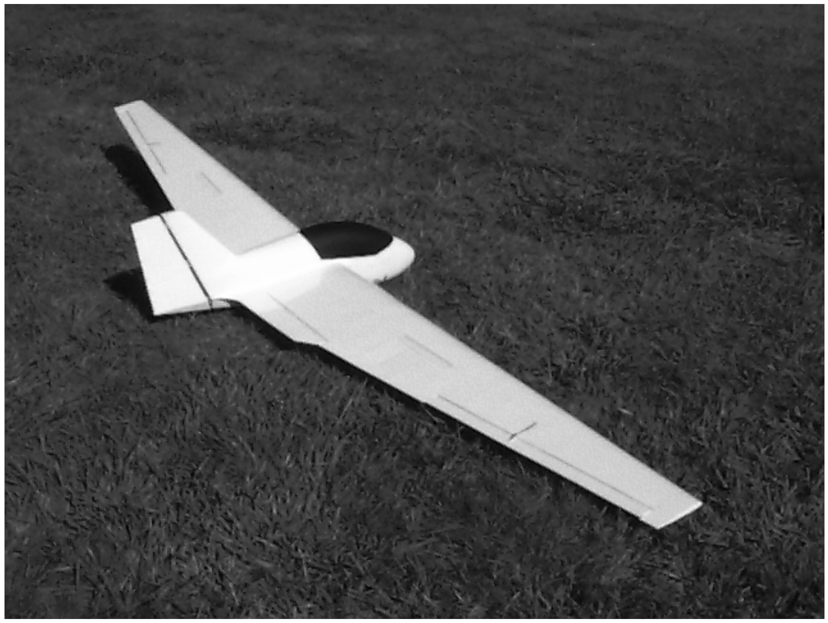
1/4 Scale Pioneer II-D at 60 Acres

Jim Marske's "Pioneer II-D," mentioned many times over the years we have been writing this column, was the subject of our first venture into scale sailplanes. Our model, constructed in 1989, was built to quarter scale and flew successfully at the first Scale Fun Fly in Richland Washington that year. A couple of years later it got kind of crumpled on the same slope, victim of pilot error. Both wings were broken about half way out, and the front of the fuselage was pushed in. A member of the Seattle Area Soaring Society bought the carcass and set about the task of repairing the damage.

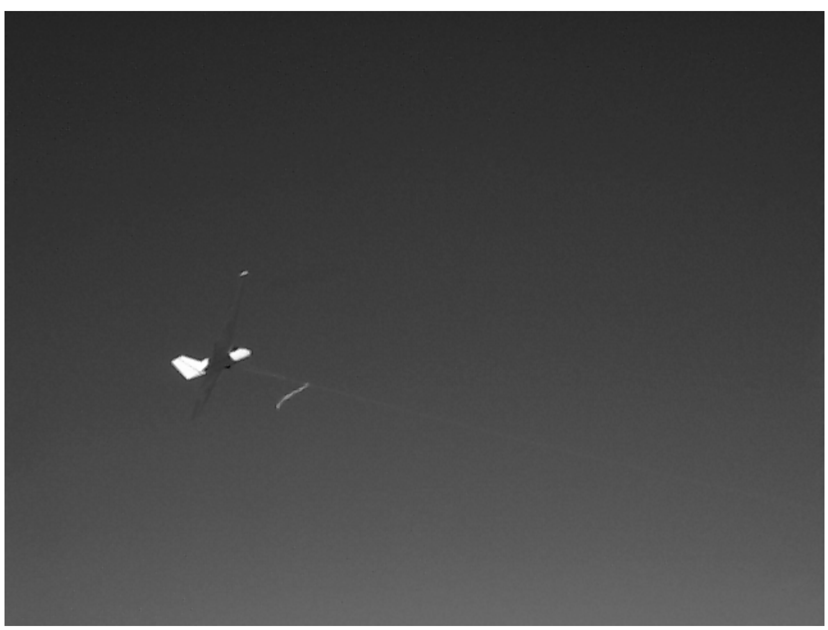
Around mid summer of this year we received a call from Don Bailey, also a SASS member, who had subsequently purchased the partially repaired glider. Don had completed the repairs, recovered the wings and vertical tail, and painted the fuselage. Armed with the correct CG location and control throw information, he planned to enter the Pioneer in an upcoming scale contest at 60 Acres in Redmond. We were pleasantly surprised to hear that our creation had not only been reborn, but was to be flown in thermal conditions, something we never had the chance to accomplish.

Don Bailey, Bill, and the Pioneer II-D at 60 Acres

At 60 Acres in August, we got a chance to see first hand the change which had been imparted. Don had replaced the releasable tow hooks with more standard fare and constructed a bridle which snapped onto the end of the winch line. A large battery pack reduced the necessary lead in the nose to a minimum. Now all white, the Pioneer looked just like its full size counterparts.



Before taking it up on the winch, we rechecked the CG and control throws. For safety, a bit more lead was added to the nose. Control throws looked good, and Don set up the transmitter to mix rudder with aileron. The first launch offered a surprise in the form of a tip stall relatively close to the ground! Don corrected rapidly, however, and once off the towline the Pioneer settled into a rapid glide. The tip stall problem, which was never experienced during slope flying, should not have come as such a surprise. On the slope,



very high lift coefficients were never needed. A winch launch, however, puts very high lift demands on the wing. A relatively small chord at the wing tip, coupled with the airfoil of the full size Pioneer II-D, makes tip stall a likely difficulty.

With some down trim in the elevator, the second launch was better, with no evidence of tip stall. Over the next few launches and glides Don got things pretty well sorted out. Some lead was taken out of the nose, the down trim in the elevator was retained, aileron-rudder mix was turned off, and a trim tape trip strip was applied to the outer third of the wing at about 20% chord.

These changes, taken one at a time, almost eliminated the tip stall problem, so that it became evident only when the angle of bank approached about 50 degrees. Despite having to hold the bank angle to below 50 degrees, Don did manage to get some thermal flying in during the contest. The Pioneer appears very realistic in flight.

Don completed all of Saturday's contest flights and took the Pioneer out for a second day of flying on Sunday. Now somewhat used to the Pioneer's flying characteristics, he seems satisfied with its performance and told us he plans to finish the project, to include full detailing of the cockpit and fabrication of a clear canopy.

We're looking forward to seeing the Pioneer compete again later this year.

Special thanks to Steve Cameron for taking pictures while we were assisting Don at 60 Acres.

An additional note:

Don eventually fixed the tip stalling problem by placing a couple degrees of washout into both wings. This is not usually a recommended procedure for plank planforms, as it actually decreases stability. However, Don was desperate. Perhaps washin was put into the wings during repairs, and the washout Don added actually brought the wing tips into a zero incidence condition as related to the root.

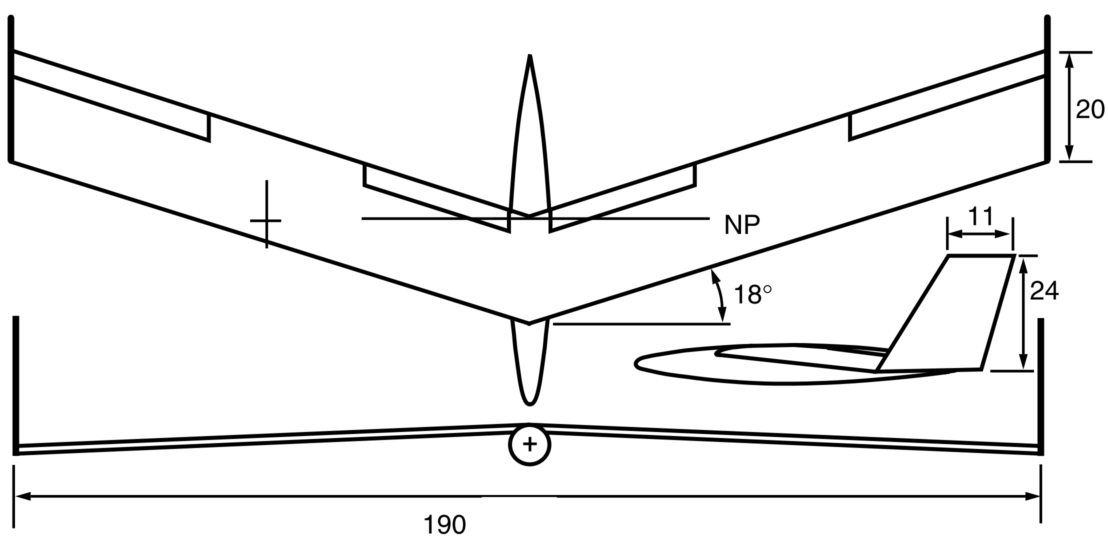
Don was out at 60 Acres on 31 August 1997, and was able to fly pretty far out, taking advantage of some light ridge lift at the east end of the field. He was also able to bank at angles greater than 60 degrees. One flight lasted well over 15 minutes. He said it is sometimes difficult to keep track of the actual pitch angle of the aircraft, as the fuselage is short and relatively chunky, but he is now extremely pleased with the overall flight characteristics.

"Joined 1," a super fast 'wing, and some thoughts on airfoil thickness

Here's a super fast 'wing from Germany, the "Joined 1" by Hans Jürgen Unverferth. This relatively small tailless design, piloted by Peter Kowalski, flew through a measured 200 meter course in under three seconds — a speed of over 150 miles per hour. "Joined 1" uses the EH 1.0/7.0, which is essentially a thinned down version of the EH 1.0/9.0 section.

There is now a move by designers of conventional tailed aircraft to utilize thinner wing sections. Two advantages can usually be derived from going to a thinner section: lower drag and less weight. Drag is lowered because there is less frontal area, while weight decreases because less material is required to construct the wing. This latter point is especially important during the construction of outboard wing panels, as any additional mass in that area translates into inertia which inhibits roll response.

Using a thin airfoil on a tailless planform does not necessarily yield such positive results, however.



JOINED 1

SPECIFICATIONS:

Span: 190cm	Wing area 38dm^2
Chord: 20cm	Weight: 1100gr
Section: EH 1.0/7.0	Glass cloth: 27gr/dm^2

- While drag may indeed be lowered by using a thinner section, tailless planforms are inherently faster than their tailed counterparts from the outset. “Joined 1,” with its near record breaking performance, uses a section which is 7% thick.

- There are also structural considerations. Swept wings need both stiffness in the span-wise direction and torsional rigidity. These two goals are better accomplished with a thicker section because torsional rigidity is increased as the wing section becomes deeper, and rigidity along the span is a function of spar height.

These two points should get you to thinking about the appropriateness of a 9% section for a tailless thermal soarer. A 10% or 12% section, with 2% to 3% camber, may give superior thermal performance and provide a wider speed range. A thicker section will be better able to provide the strength needed for winch launching, yet high speed travel between thermals should not be adversely affected to any great degree.

Information from *Silent Flight*, Dave Jones Editor, Spring 1992, and personal correspondence with Dave Jones.

A Possible Solution to Adverse Yaw in Plank Planforms

In a previous column (August 1992) we discussed the possible effects of differential on the performance of tailless planforms. Since that column, we have been involved in effective solutions for two types of control problems, one involving a plank, which we'll discus this month, the other involving a swept wing. Both difficulties are related to aileron differential.

The first case centered on our favorite design, Dave Jones' "Blackbird 2M." The "Blackbird 2M" is essentially a plank type planform which can use either the CJ 3309 airfoil (3% camber at 30% chord, 9% thick) or the CJ $25^{2}09$ (2.5% camber at 25% chord, 9% thick). Both of these are reflexed sections with strong positive pitching moments.

The original elevon design for the "Blackbird 2M" was of the "Frise" type. The Frise aileron utilizes a rearward hinge line such that when the aileron is deflected upward the leading edge protrudes into the airflow along the wing bottom surface. (See Figure 1) This produces some amount of drag, and effectively counteracts adverse yaw.

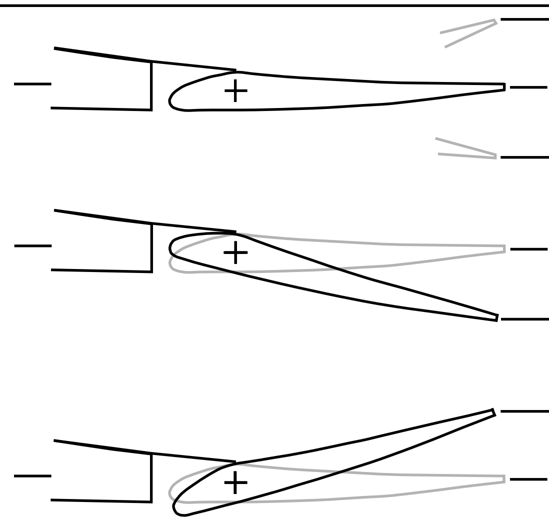


Figure 1

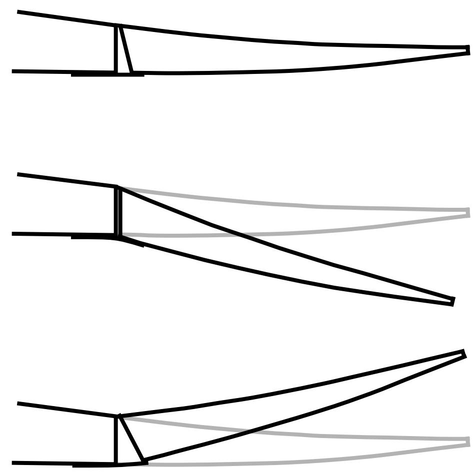


Figure 2

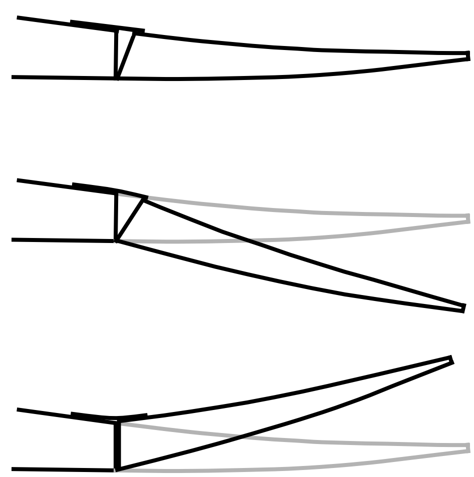


Figure 3

After building several Blackbirds of various sizes, we noted they all shared a common fault. When flying in a straight line, alternating left and right aileron input did not produce rolling motion. Rather, the wing would simply oscillate around the yaw axis.

Our initial attempt at inhibiting this tendency was to hinge the elevon from the top surface, thus eliminating the Frise type action. (See Figure 2) The “Blackbird 2M” which we took to Australia in 1993 utilizes this hinging method. The yawing motion resulting from the alternating input described above is reduced but not eliminated. On the other hand, up elevator is no longer accompanied by the increased drag of the control surface leading edge protruding into the airflow.

When constructing a foam core version of the Blackbird, we decided to hinge the elevons from the bottom surface. (See Figure 3) Hinging from the bottom was no more difficult than hinging from the top, but the elevon area is actually reduced as it is deflected upward. Bottom hinging thus gives reverse differential action. Yaw response to alternating aileron input has been nearly entirely eliminated, roll control is very precise, and beautiful coordinated turns can be easily made. This is the smoothest flying Blackbird of all, including our XC version, which is significantly larger.

Next time we’ll describe an effective solution to a tip stall problem in a swept ’wing.

Tails! You lose!

A Possible Solution to Tip Stalling in Swept 'Wings

Last time we presented a simple solution to a yawing problem and promised to describe an effective solution for tip stalling in swept wing tailless.

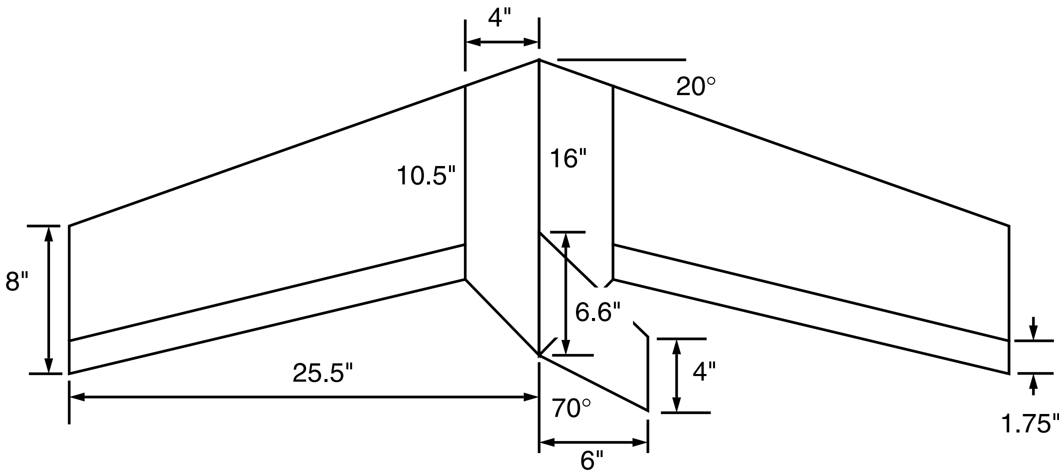
Alan Halleck, a fellow enthusiast of tailless planforms, some years ago cut a foam core for a swept wing planform. This was one of the first planforms Alan designed using the Panknin computer program which he and Bill wrote. The cut wing was stored away and Alan built several other wings before coming back to it. Alan's ideas are always in flux, and so it was no surprise to hear he had trimmed the wing down to a smaller size before 'glassing it.

The wing was to be built light, as Alan had planned it as a thermal 'ship. Since the wing twist started at the half span point, the removal of the wing tips substantially reduced the built in washout. This latter point didn't seem to bother Alan as he was sure he had put in a bit more twist than needed.

At the thermal field, the foreshortened wing, when banked for a tight thermal turn, tip stalled viciously, taking nearly a full turn and a lot of altitude to recover. Alan's 'phone call to us, while not an act of desperation, was clearly highly motivated. Alan covered the relevant points: the tip chord, due to the shortened span, was broader than originally anticipated for the design; straight and level flight posed no problems, so pitch stability was sufficient; the CG was in the correct position.

Since no solutions immediately came to mind, the conversation drifted to other topics. Alan started talking about his computer radio and all of the exciting things it could do, like mixing differential into and between various control surfaces. This got our attention! It turned out Alan had put nearly 2:1 differential in the aileron function of the transmitter. After some discussion, it was decided the differential was most likely the problem, and Alan decided he would try flying his creation with all of the differential removed.

Removal of all aileron differential completely eliminated the tip stalling problem, and turned an otherwise nasty airplane into a relatively docile flyer. Alan has since flown the 'wing successfully both at the slope during light lift conditions and in a thermal environment.



Alan Halleck's Thermal Soarer

This episode has illustrated several points to be considered during design, construction and test flying of swept wing tailless sailplanes:

- match tip chord and minimum flying speed — make sure the chosen section can operate effectively at the expected low Reynolds number conditions;
- compute sweep angle, wing washout, and CG location accurately — check these again during construction and once again before flight;
- perform initial test flights with no aileron differential — any addition of aileron differential for subsequent flying should be approached with caution.

Following the above guidelines should prevent or eliminate tip stalling.

Specific information on how aileron differential may degrade the performance of planks and swept wings may be found in our "On the 'Wing..." column in the August 1992 issue of *RC Soaring Digest*. This column is also available as a reprint in "On the 'Wing... the book."

Komets!

Our aviation book collection keeps growing, mainly due to our love of used book stores. A recent trip to San Diego California netted “Rocket Fighter,” by William Green, a book which describes many of the world’s rocket powered fighter aircraft and is part of Ballantine’s Illustrated History of World War II series. In looking through Green’s book, we came to realize the significant number of swept wing tailless aircraft which were a part of the Messerschmitt Me 163 “Komet” development program.

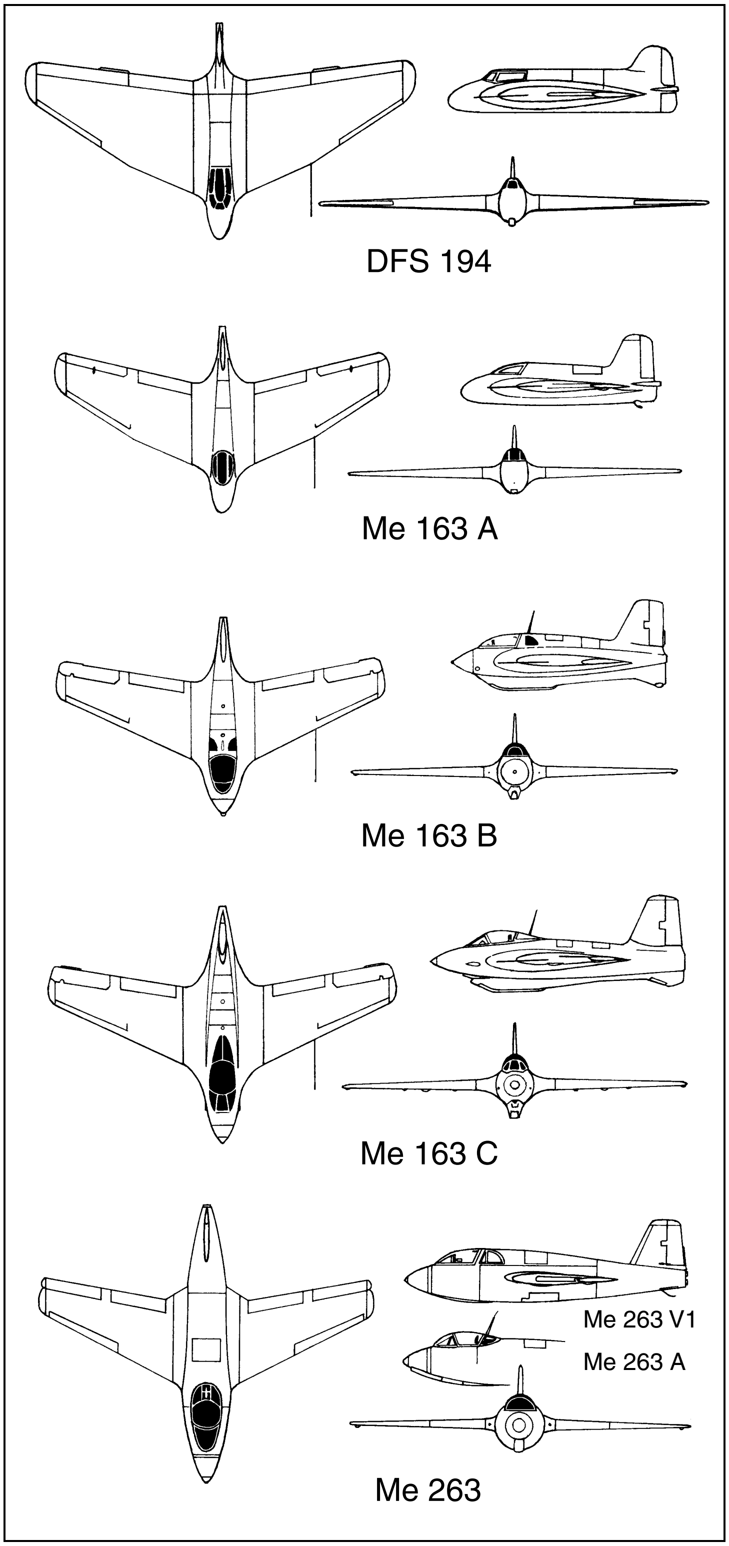
Then while placing our new acquisition on the library shelf, we found ourselves looking at several other books focused on the “Komet,” and World War Two aircraft in general. And for some reason we suddenly realized that each of the “Komet” project prototypes was first flown without power. In fact, all five versions were towed to altitude for at least their initial flight. As PSS subjects, all five would do well, and in fact the Me 163 B has been kitted by several manufacturers, both as a PSS model and for conventional piston engine power.

The DFS 194, the real pioneer in what was to become the “Komet” series, is somewhat lacking so far as streamlining is concerned. But the original had a fairly good glide ratio, and a thermalling model may not be out of the question. The Me 163 A is in the same general class.

The popularity of the Me 163 B is understandable, but we feel the good looks of the Me 163 C have been overlooked for too long. Perhaps this is because people have been under the mistaken impression that it did not fly. Both the Me 163 C and Me 263 did in fact fly as gliders.

We hope that presenting this information along with the accompanying three-views will stimulate readers to try their hand at producing models of these great aircraft.

It should be noted the information for the various designations was gathered from several sources, with sometimes conflicting information. There are hopefully no inaccuracies.


DFS 194
Me 163 A
Me 163 B
Me 163 C
Me 263 V1
Me 263 A
Me 263

DFS 194

The *Deutschen Forschungsinstitut für Segelflug* (German Research Institute for Sailplanes) DFS 194 was originally designed to be powered by a pusher propeller and conventional gasoline engine, but served instead as the testbed for the first of the Walter "cold" powerplants. As a glider it had a glide ratio of better than 20 to 1. Under rocket power, with 882 pounds of thrust, it reached 342 m.p.h., even though stressed for only 190 m.p.h. maximum speed.

Me 163 A

First flown as a glider on February 13, 1941, and with rocket power (1653 pounds of thrust) on August 13 of that year. Despite its relatively low aspect ratio of 1:4.4 and rather bulbous fuselage, the Me 163 A had a sink rate of just 5 ft./sec. at 137 m.p.h. The performance of the Me 163 A as a glider was very impressive; Ernst Udet witnessed one of the gliding flights, with speeds of over 400 m.p.h., and was astounded to learn the aircraft was not powered. Early trials showed the airframe easily capable of 550 m.p.h., and by the first part of October the Me 163 A had exceeded 1000 k.p.h. or 623.85 m.p.h. (Mach 0.85). Compressibility effects near the wing tips had a detrimental effect on stability, and this lead to a change in wing sweep angle and amount of washout for the B model. A number of glider only airframes, designated Me 163 A-0, were constructed by the Wolf Hirth firm for use in later pilot training.

Me 163 B

This model, dubbed "Komet," became an operational fighter in May of 1944 with first delivery to Jagdgeschwader 400. The "hot" rocket motor produced 3750 pounds of thrust for six minutes. The fuselage was of light alloy, while the wings, with a spar at about 25% chord, were of wood. Control surfaces were fabric covered. Altitudes of over 39,000 ft. could be reached in just 3.5 minutes! On July 6 1944 Rudolph Opitz flew the Me 163 B V18, equipped with a second smaller combustion chamber for greater cruise duration, to a speed of 702 m.p.h. during climb calibration trials.

Me 163 C

The Me 163 C was designed to make use of a refined powerplant with greater duration. Three of the C versions were built, only one was flown, and never under power. Because of the failure of the new motor to provide the additional duration, further development was dropped in favor of the Me 163 D, and all three of the C models were destroyed a short time later, at the end of the war.

Me 163 D/Ju 248/Me 263

This Me 163 D was somewhat larger than the Me 163 C and had a retractable tricycle landing gear. Plans included both a pressurized cabin and an advanced powerplant with an auxiliary cruise combustion chamber. Production models were to have a bubble canopy. Designed by Messerschmitt but to be produced by Junkers, hence the Ju 248 designation; Messerschmitt successfully petitioned to have the designation prefix changed back to Me following successful initial trials. The Me 263 was flown as both a glider and under power but, because of the end of the war, tooling was not completed and it was never put into production.

Within the references noted below, the two books by Green contain some very fine 3-views of the various "Komet" models, while the two Schiffer publications present several paint schemes. The Späte book contains some color photographs, the emblem of the Jagdgeschwader 400, and reproductions of factory drawings. Wooldridge's "Winged Wonders" integrates the "Komet" program into the overall history of tailless aircraft development.

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Wooldridge, E.T. Winged Wonders. Smithsonian Institution Press, Washington D.C. 1988.

Zeigler, Mano. Messerschmitt Me 163 Komet. Schiffer Publishing, Ltd., West Chester PA. 1990. (This is a translation by Dr. Edward Force of *Messerschmitt Me 163 Komet*. Podzun-Palla Verlag, Friedberg Germany. 1977.)

Sections with Near Zero Pitching Moments — Good Choices for Plank Planforms?

While looking over our tailless aircraft plans collection, we were struck by the tremendous changes in airfoils through the decades and the increased performance which has been the result of this evolution. The airfoil characteristic which has changed the most during this process, particularly for plank planforms, is airfoil pitching moment. This month's column is devoted to exploring the reasons for this overall design tendency.

It is sometimes helpful to examine tailed aircraft before looking at tailless configurations, and this is particularly true in this case. A conventional tailed aircraft will always tend to fly at that speed where the force produced by the horizontal stabilizer exactly counterbalances the combination of the wing pitching moment and the downforce produced by center of gravity being ahead of the neutral point. These forces and their interactions are depicted in Figure 1.

The wing pitching moment in most cases is negative (nose down) due to camber. A center of gravity ahead of the aircraft neutral point also produces a nose down force. The more negative the wing pitching moment and/or the more forward the CG, the more downforce must be produced by the horizontal stabilizer. Note the horizontal stabilizer downforce is produced

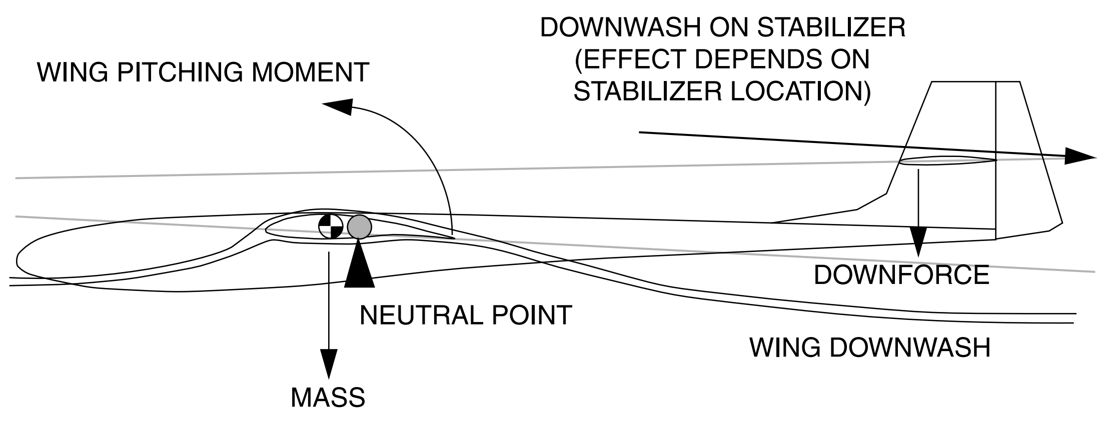

Figure 1

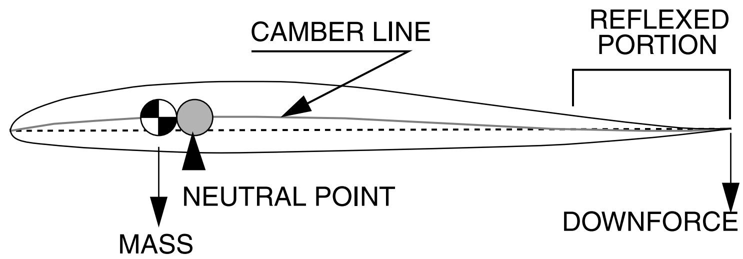

Figure 2

through a combination of angular difference between the wing and tail, and the downwash of the wing upon the tail.

A tailless planform is subject to the same aerodynamic laws as a conventional tailed aircraft. An advantage of tailless configurations, however, is that there is no downwash effect to calculate during the design process. The wing section will incorporate camber so as to achieve a higher maximum coefficient of lift, but since there is no horizontal stabilizer, the wing itself must also provide the down force required to achieve aerodynamic balance. For swept back wings, the down force is generated by the wing tips, while for plank planforms the rear portion of the airfoil is curved upward by a reversing (reflexing) of the camber line, as shown in Figure 2. This reflexing of the camber line must be carefully tailored to provide sufficient down force without unnecessary drag.

For a plank planform, section reflex directly determines speed. Imagine the actions of the aircraft at various velocities with the reflex remaining constant. If the aircraft is flying too slow, the CG ahead of the neutral point tends to pull the nose down, thus increasing speed. If, on the other hand, the velocity is too high, the reflexed area of the section produces a downforce which is greater than that of the effect of the CG. In this case the nose of the aircraft is forced up and the speed drops. These two cases are illustrated in Figure 3. For a given amount of reflex and a specific CG location there is one flying speed where the two forces are in balance.

For radio controlled and manned planks, a moveable CG may provide some speed latitude. The CG is moved forward for higher speeds and back for lower speeds. See Figure 4 for an explanation of how this works.
Free flight planks, which require large amounts of stability, have fixed forward CG locations and large amounts of reflex. For power models, the thrust line must be adjusted so any looping tendency due to higher speed while under power is counteracted by engine thrust.

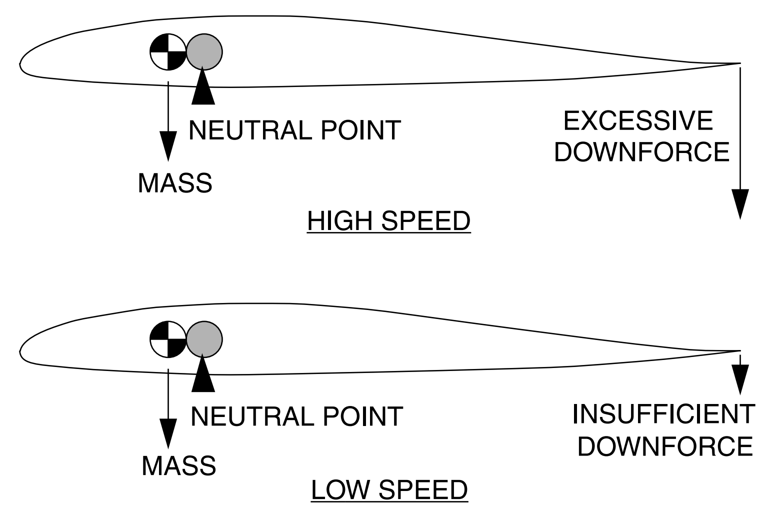

Figure 3

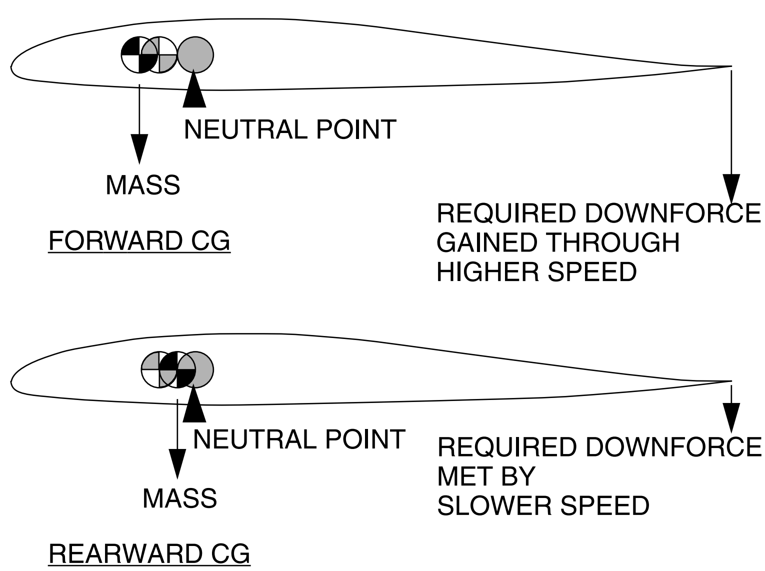

Figure 4

In the early days of tailless aircraft design, there was a trend to incorporate a large amount of reflex in the wing section, just as for free flight models. This dictated a forward CG position which made for very stable aircraft, but performance suffered due to high drag. In addition, excessive downforce robbed the aircraft of generated lift as some of the lift generated by the forward portion of the wing was counteracted by the down force generated by the rear portion.

Over time, the amount of reflex designed into airfoil sections for plank planforms, for both full size and model aircraft, has gradually decreased. Along with this reduction in reflex has come a reduction in section drag. The accompanying Table gives an overall idea of the evolution of sections deemed appropriate for plank planforms. Due to lack of published data, moment coefficients for this Table were frequently obtained through use of the cited Lounsbery code.

Speed can be controlled over a wide range by means of full span reflex trim. There is no need to resort to a moveable CG in this case. In addition, overall performance is improved because of lower drag during nearly all flight regimes when compared to identical planforms without such full span camber changing capability. The Bird Works (Kindrick) *Zipper* uses a full span camber changing system to excellent effect. The wing has a moderately positive pitching moment at low speeds due to up trim, but the pitching moment is near zero at very high speed when neutral trim is employed. See Figure 5.

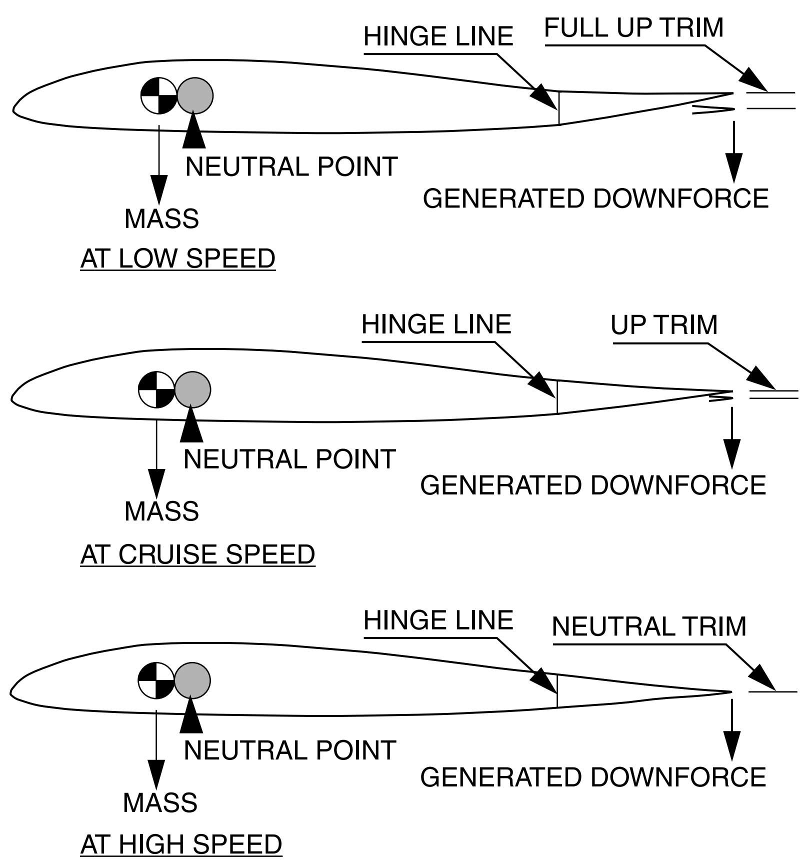

Figure 5

As can be seen from the Table below, referenced earlier, the pitching moment of sections designed for use on plank planforms has decreased markedly over the years. Parallel performance improvements have resulted. If you are considering design and construction of a plank planform, perhaps this month's column will entice you to consider using a section with a low pitching moment and appropriate control surfaces.

Designer/Builder: A/C Designation	Section (Year)	c_m
FULL SIZE		
Fauvel AV.361	Fauvel F2 17% (1960)	0.0685*
Marske Pioneer II-D	NACA 43012Ax.833-75 (root) NACA 43012A-75 (tip) (~1985)	0.0185* 0.0212*
Marske & Roncz Genesis 1	Genesis, proprietary (root) (1994)	0.0174*
MODEL		
Jones Raven and Blackbird 2M	CJ 3309 (1984)	0.0323*
Jones Blackbird 2M	CJ 25^2-09 (1993)	0.0249*
Jones/Kuhlman: Blackbird 2.3M.mod	S 5020 (1994)	0.000597
Kindrick: Zipper*	EH 1.0/9.0	0.000189

* calculated using Lounsbery code

References and Sources:

The Birdworks, P.O. Box 1302, Port Orford OR 97465.

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Lounsbery, Walter, “Simple Calculation of Airfoil Moment Coefficients,” *Soartech 1*, H.A. (Herk) Stokely, 1504 Horseshoe Circle, Virginia Beach VA 23451.

Marske, Jim, “Experiment in Flying Wing Sailplanes,” (self-published), 130 Crestwood Dr., Michigan City IN 46360, 1970.

Hans-Jürgen Unverferth's "CO^7 V4"

Andrew MacDonald, formerly of Adelaide S.A., Australia, has provided us with an entire package of information about Hans-Jürgen Unverferth's most recent creations — enough for a series of four articles. This month we'll focus on Hans-Jürgen's CO^7 (CEOSIEBEN), a high performance swept wing sailplane for the F3B, F3F, and F3J environments. Coordinates and basic aerodynamic data for the three airfoil sections used on CO^7 will be published in the next issue of *RCSD*. That will be followed by a description of Joined II, the follow-up model to the Joined I which was described in our April '96 column. A presentation of Hans-Jürgen's thoughts on the potential performance of tailless sailplanes will make the fourth and last installment of the series.

And now on to CO^7!

CO^7 V4 is the model Hans-Jürgen used to win the Kaltenkirchen Cup in 1995. The annual Kaltenkirchen contest is for tailless sailplanes only, but is based on the F3B venue and is intensely competitive — a real test of any soaring machine.

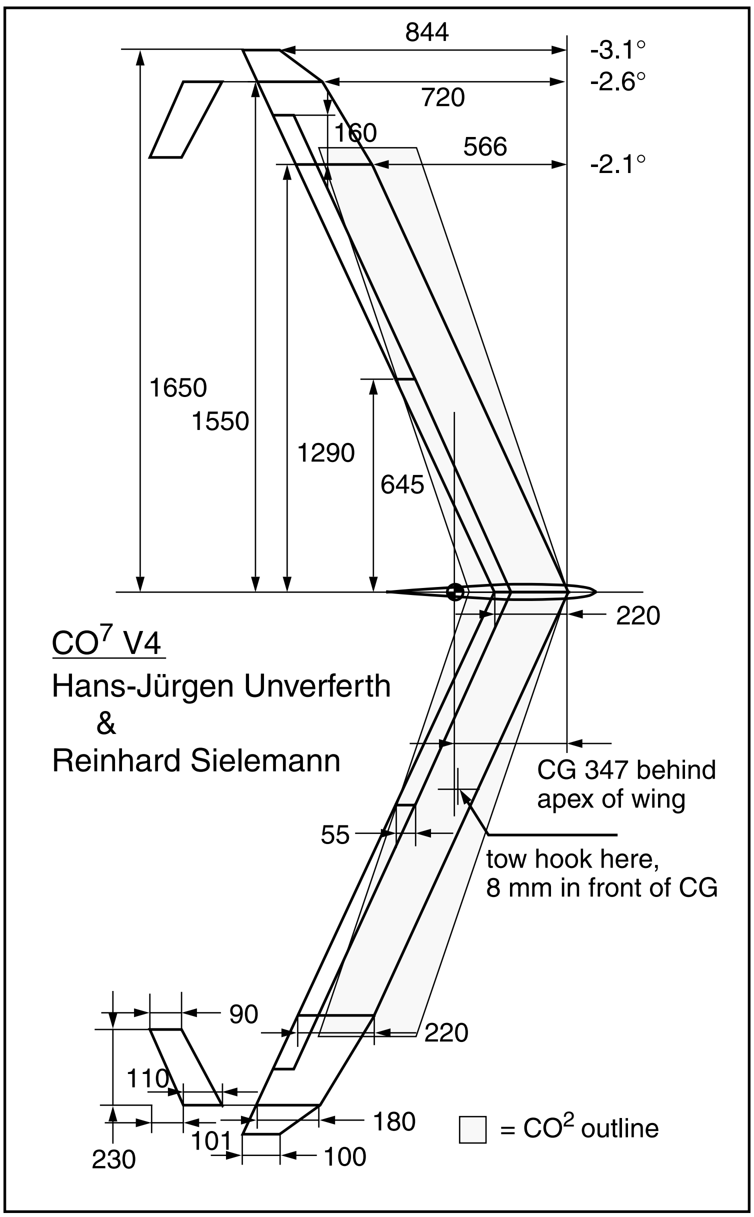
CO^7 is a direct descendant of CO^2, a very successful model which has been kitted and remains very popular in Europe. CO^2 used a carbon fiber spar, and both Hans-Jürgen and his friend were very impressed with its rigidity. After taking the first CO^2 wing out of the vacuum bag, both said "Oh..," and the name C (carbon) O^2 (two "oh.."s) came to be. Yes, CO^3, CO^4, CO^5, and CO^6 have been built!

CO^7 consists of a moulded composite airframe using fiberglass and carbon fiber. The wing is entirely flat and is built in three separate pieces which assemble for flying. It differs from CO^2 in several respects:

- it has a higher aspect ratio, about 16.5 vs. 9.0,
- it has a greater sweep angle, nearly 25 degrees vs. 18 degrees,
- it incorporates a semi-crescent planform while CO^2 used a simple constant chord wing,
- its winglets are inboard from the wing tip,
- it utilizes a more complex wing twist geometry.

The accompanying diagram shows the CO^7 planform and relevant dimensions, including wing twist and locations of the center of gravity and tow hooks. Note the center of gravity is within the aft fuselage. This is an excellent location, as the model is well balanced while being held for winch launching. Also be aware there are two tow hooks, each mounted at identical spots on both wings. A bridle is needed, but launch loads are thus spread relatively evenly across the entire span, rather than being concentrated near the fuselage centerline.

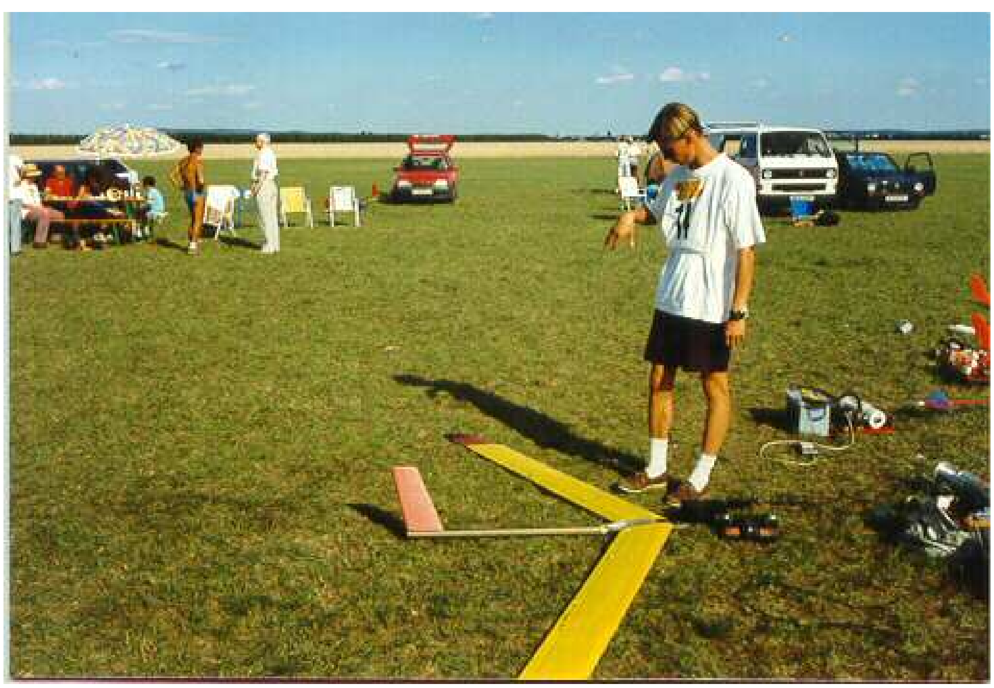
Recent information from Hans-Jürgen indicates CO^7 will soon be commercially available, produced by a fellow in Russia whose experience is in free flight. He should be able to turn out some very light weight, yet strong, models.



Hans-Jürgen Unverferth and CO^7.

A CO^{7}at launch!

Hans-Hürgen Unverferth at the controls as CO^5 is launched.



CO^6, a departure from the winglet planforms of others in the CO^x series.

CO^7 V4 Sections: the RS Series

These are the sections used on Hans-Jürgen Unverferth's CO^7 V4. As they are used in a rather unique way on this sailplane, refer to the CO^7 V4 three-view published previously.

The RS001 is used unchanged from the root to the first taper break at 1290 mm — that's over 78% of the span!

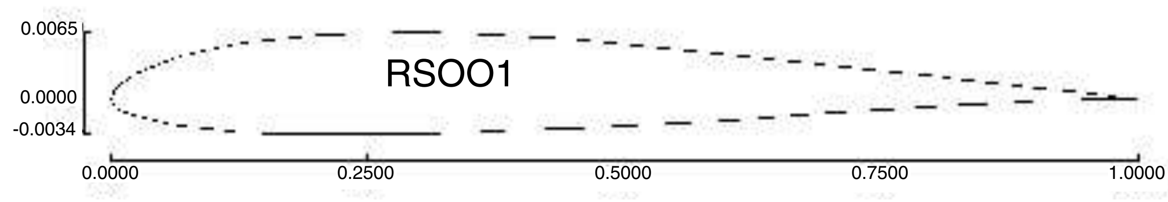
The section designated RS001M05 is used at the second taper break, at 1550 mm. The 260 mm distance between the first and second taper break serves as a transition from the RS001 to the RS001M05 section.

The RS001T10, a symmetrical section used only at the wing tip, terminates a transition from the RS001M05. This transition occurs over the last 100 mm of the wing, from the second taper break.

Note both the RS001 and RS001M05 have substantial negative pitching moments. In fact, the only place a zero pitching moment section is used on the CO^7 V4 is at the wing tip. This means the entire wing is composed of sections with negative pitching moments. Hence the need for several degrees of washout, despite a relatively severe sweep angle of 25 degrees. CO^7 V4 thus stands in direct contrast to Hans-Jürgen's previous designs which have used sections with near zero pitching moments across the entire span and incorporated only a degree or so of wing twist.

For those contemplating construction of CO^7, be advised Hans-Jürgen states there are no performance improvements to be made by changing the wing tip section.

The successor to the "Joined 1," described in the April issue, will be the focus of our next column.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RSOO1
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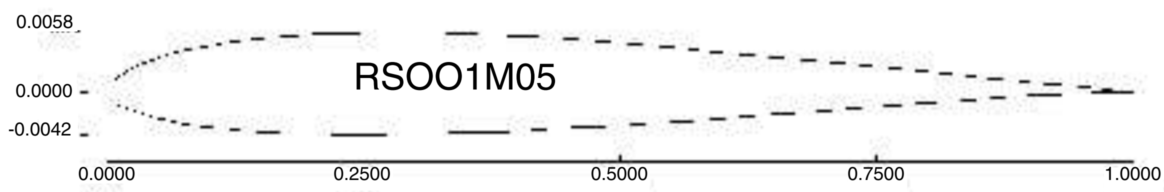
0.7500
1.0000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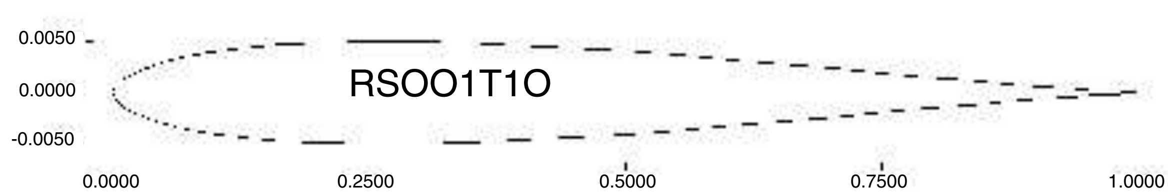
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RSOO1T1O
0.0000
0.2500
0.5000
0.7500
1.0000

RS001		
n	x	y
0	100.0000	0.0000
1	99.7260	0.0280
2	98.9070	0.1220
3	97.5530	0.2920
4	95.6770	0.5260
5	93.3010	0.8070
6	90.4510	1.1330
7	87.1570	1.5070
8	83.4570	1.9250
9	79.3890	2.3730
10	75.0000	2.8500
11	70.3370	3.3540
12	65.4510	3.8570
13	60.3960	4.3530
14	55.2260	4.8890
15	50.0000	5.4360
16	44.7740	5.8890
17	39.6040	6.2150
18	34.5490	6.4290
19	29.6630	6.5190
20	25.0000	6.4720
21	20.6110	6.2810
22	16.5430	5.9470
23	12.8430	5.4780
24	9.5490	4.8840
25	6.6990	4.1780
26	4.3230	3.3730
27	2.4470	2.4900
28	1.0930	1.5640
29	0.2740	0.6920
30	0.0000	0.0000

RS001		
n	x	y
31	0.2740	-0.5390
32	1.0930	-1.0430
33	2.4470	-1.5520
34	4.3230	-2.0360
35	6.6990	-2.4800
36	9.5490	-2.8510
37	12.8430	-3.1210
38	16.5430	-3.2880
39	20.6110	-3.3620
40	25.0000	-3.3550
41	29.6630	-3.2800
42	34.5490	-3.1460
43	39.6040	-2.9660
44	44.7740	-2.7510
45	50.0000	-2.5200
46	55.2260	-2.2710
47	60.3960	-1.9670
48	65.4510	-1.6210
49	70.3370	-1.2850
50	75.0000	-0.9740
51	79.3890	-0.6940
52	83.4570	-0.4570
53	87.1570	-0.2640
54	90.4510	-0.1190
55	93.3010	-0.0260
56	95.6770	0.0210
57	97.5530	0.0320
58	98.9070	0.0210
59	99.7260	0.0060
60	100.0000	0.0000

RS001M05		
n	x	y
0	100.0000	0.0000
1	99.9013	0.0068
2	99.6057	0.0288
3	99.1144	0.0688
4	98.4292	0.1298
5	97.5528	0.2120
6	96.4888	0.3138
7	95.2414	0.4326
8	93.8153	0.5668
9	92.2164	0.7172
10	90.4508	0.8846
11	88.5257	1.0700
12	86.4484	1.2730
13	84.2274	1.4918
14	81.8712	1.7231
15	79.3893	1.9657
16	76.7913	2.2202
17	74.0877	2.4867
18	71.2890	2.7625
19	68.4062	3.0418
20	65.4508	3.3202
21	62.4345	3.5962
22	59.3691	3.8770
23	56.2667	4.1660
24	53.1395	4.4581
25	50.0000	4.7394

RS001M05		
n	x	y
26	46.8605	4.9904
27	43.7333	5.2071
28	40.6309	5.3871
29	37.5655	5.5336
30	34.5492	5.6472
31	31.5938	5.7209
32	28.7110	5.7550
33	25.9123	5.7452
34	23.2087	5.6899
35	20.6107	5.5904
36	18.1288	5.4420
37	15.7726	5.2498
38	13.5516	5.0119
39	11.4743	4.7294
40	9.5492	4.4072
41	7.7836	4.0417
42	6.1847	3.6421
43	4.7586	3.2096
44	3.5112	2.7499
45	2.4472	2.2720
46	1.5708	1.7729
47	0.8856	1.2782
48	0.3943	0.8042
49	0.0987	0.3697
50	0.0000	0.0000

RS001M05		
n	x	y
51	0.0987	-0.3409
52	0.3943	-0.6971
53	0.8856	-1.0592
54	1.5708	-1.4298
55	2.4472	-1.8030
56	3.5112	-2.1598
57	4.7586	-2.5039
58	6.1847	-2.8281
59	7.7836	-3.1250
60	9.5492	-3.3907
61	11.4743	-3.6152
62	13.5516	-3.8022
63	15.7726	-3.9492
64	18.1288	-4.0578
65	20.6107	-4.1310
66	23.2087	-4.1672
67	25.9123	-4.1716
68	28.7110	-4.1448
69	31.5938	-4.0882
70	34.5492	-4.0056
71	37.5655	-3.8982
72	40.6309	-3.7704
73	43.7333	-3.6233
74	46.8605	-3.4593
75	50.0000	-3.2814

RS001M05		
n	x	y
76	53.1395	-3.0896
77	56.2667	-2.8841
78	59.3691	-2.6647
79	62.4345	-2.4352
80	65.4508	-2.2023
81	68.4062	-1.9718
82	71.2890	-1.7468
83	74.0877	-1.5291
84	76.7913	-1.3214
85	79.3893	-1.1262
86	81.8712	-0.9460
87	84.2274	-0.7800
88	86.4484	-0.6288
89	88.5257	-0.4944
90	90.4508	-0.3776
91	92.2164	-0.2801
92	93.8153	-0.2000
93	95.2414	-0.1359
94	96.4888	-0.0865
95	97.5528	-0.0500
96	98.4292	-0.0259
97	99.1144	-0.0113
98	99.6057	-0.0040
99	99.9013	-0.0008
100	100.0000	0.0000

RSOO1T1O		
n	x	y
0	100.0000	0.0000
1	99.7260	0.0112
2	98.9070	0.0513
3	97.5530	0.1321
4	95.6770	0.2566
5	93.3010	0.4233
6	90.4510	0.6362
7	87.1570	0.8999
8	83.4570	1.2104
9	79.3890	1.5584
10	75.0000	1.9431
11	70.3370	2.3572
12	65.4510	2.7835
13	60.3960	3.2114
14	55.2260	3.6382
15	50.0000	4.0427
16	44.7740	4.3902
17	39.6040	4.6651
18	34.5490	4.8653
19	29.6630	4.9792
20	25.0000	4.9934
21	20.6110	4.8999
22	16.5430	4.6926
23	12.8430	4.3694
24	9.5490	3.9304
25	6.6990	3.3831
26	4.3230	2.7485
27	2.4470	2.0539
28	1.0930	1.3247
29	0.2740	0.6255
30	0.0000	0.0000

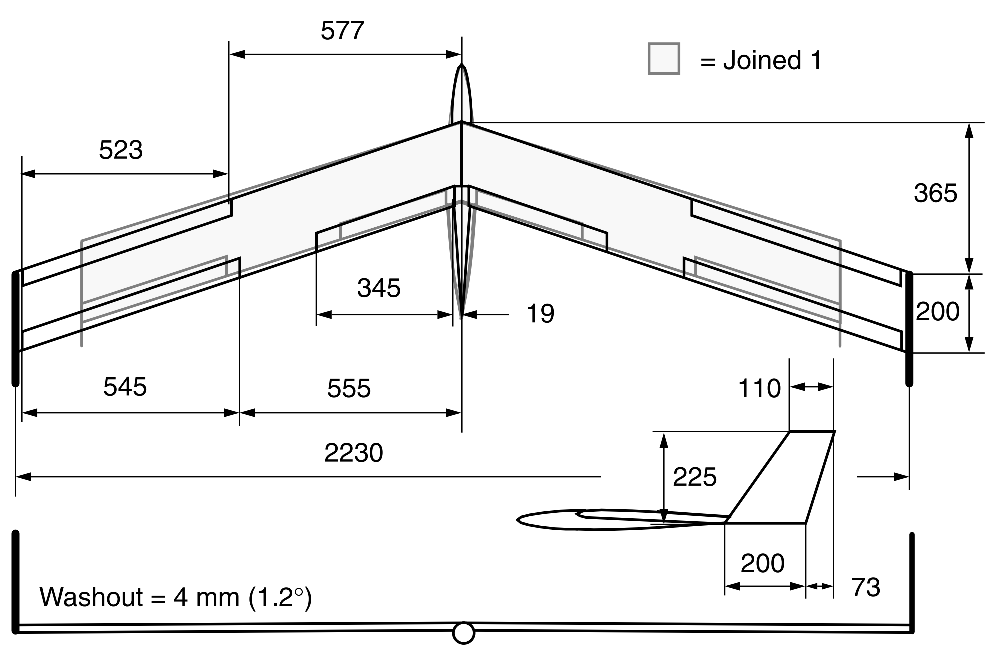
RSOO1T1O		
n	x	y
31	0.2740	-0.6255
32	1.0930	-1.3247
33	2.4470	-2.0539
34	4.3230	-2.7485
35	6.6990	-3.3831
36	9.5490	-3.9304
37	12.8430	-4.3694
38	16.5430	-4.6926
39	20.6110	-4.8999
40	25.0000	-4.9934
41	29.6630	-4.9792
42	34.5490	-4.8653
43	39.6040	-4.6651
44	44.7740	-4.3902
45	50.0000	-4.0427
46	55.2260	-3.6382
47	60.3960	-3.2114
48	65.4510	-2.7835
49	70.3370	-2.3572
50	75.0000	-1.9431
51	79.3890	-1.5584
52	83.4570	-1.2104
53	87.1570	-0.8999
54	90.4510	-0.6362
55	93.3010	-0.4233
56	95.6770	-0.2566
57	97.5530	-0.1321
58	98.9070	-0.0513
59	99.7260	-0.0112
60	100.0000	0.0000

Hans-Jürgen Unverferth's "Joined 2"

Hans-Jürgen Unverferth is a dedicated and ardent enthusiast of tailless planforms. In an attempt to better the world speed record for RC sailplanes, he developed a relatively small swept wing glider called "Joined 1." We provided some information on this high performance sailplane in the April 1996 issue of *RC Soaring Digest*.

There are a couple of notable differences between "Joined 1" and "Joined 2." First, "Joined 1" used no wing twist at all, while "Joined 2" uses 1.2 degrees (4 mm), with the twist beginning at half span. Second, in an effort to improve landing characteristics, "Joined 2" incorporates a moveable leading edge on the outer portion of each wing.

The moveable leading edge is depicted in a photograph on the following page. The fin has been removed from the end of the wing, and the cross-section perspective shows both the moveable leading edge and the elevon.



Joined 2   Hans-Jürgen Unverferth & Reinhard Sielemann

“Joined 1” was clocked at an unofficial speed of 360 kph, or 223.7 mph. This is over a 200 meter course at an altitude below 50 meters! Hans-Jürgen said that during the record attempt he simply got the airplane lined up on the course and let go of the sticks, as any control movement at speed led to some pretty wild oscillations!

The measured speed of “Joined 2” was substantially lower, 260 kph, or 161 mph, but was much easier to fly and land. “Joined 2” is currently on display at a museum in Munich, Germany.

Next time, Hans-Jürgen’s thoughts on the future of tailless sailplanes.

Photo of Joined 2, with winglet removed, showing moveable leading edge, elevon, and winglet mounting method. EH 1.0/7.0 airfoil is used.

Achieving the Potential of Tailless Planforms

As mentioned previously, Hans-Jürgen Unverferth is an ardent supporter of tailless planforms. He has been involved in the design, construction, and flying of a large number of tailless aircraft, both glider and powered. His list of accomplishments includes “Just In Time,” “CO^2,” “CO^5,” “CO^7,” “Joined 1” and “Joined 2,” and other sailplanes, plus “Extase,” an electric powered pylon racer. He is the author of “Faszination Nurflugel” (“Fascinating Tailless“), published by Verlag für Technik und Handwerk GmbH in Germany, and is now completing a second book, entitled “Der diskrete Charme des Nurflugels” (“The Discreet Charm of Tailless”). This latest book is a continuation of “Faszination Nurflugel,” and includes detailed information on “CO^7,” his latest design.

Hans-Jürgen has been building and flying model aircraft since 1969, when he was in his teens. He quickly found radio controlled speed models, powered by OS Max .15 engines, to be his favorite. In 1976 he discovered RC sailplanes, and almost immediately became involved with F3-type models, flying F3B in international competitions.

In 1985 Hans-Jürgen was out slope soaring with a friend who was having some problems flying his tailless glider. The friend asked, “Do you want to try?” Hans-Jürgen accepted the invitation, and has been hooked on tailless aircraft ever since. Hans-Jürgen has been flying swept wing tailless entries in various contests throughout Europe, competing several times at Kaltenchirken and in the Viking Race. Additionally, he made an attempt at breaking the world speed record for gliders using his “Joined 1” design. Together with Reinhard Sielemann, Christian Behrens, Stefan Siemanns, and Christian Tallmien, Hans-Jürgen has tried to improve the performance of tailless gliders and establish them in F3B, F3E, F3J, and F3F. Despite this continuing endeavor, Hans-Jürgen feels the real values to be derived from tailless planforms are fun, a little bit of adventure, and a feeling of being one of the aviation pioneers!

Over the last decade, many advancements have been made in the realm of swept wing tailless sailplanes, both full size and model. Winch launching of tailless swept wing models, for instance, had always presented a number of difficulties, including instability on tow and lack of height upon release from the line. Both of these problems have been solved from within a rapidly evolving design process consisting of incorporation of anhedral, proper location of the tow hook relative to the CG, better airfoils, and programmable full span camber changing.

Despite these advancements and performance improvements, there is one area where tailless sailplanes have not quite met their tailed counterparts — sink rate. Tailless planforms can be designed to have excellent glide ratios, but they tend to fly significantly faster than their tailed counterparts when operating at the same wing loading. Their sink rate is therefore higher, and duration times in still air are shorter. Through careful tailoring of wing section and other planform parameters, however, this last gap in performance is rapidly shrinking.

Hans-Jürgen’s focus is now the perfection of a system by which the center of gravity can be moved in flight. Together with some amount of automatic stabilization, a moveable CG may be the key to unlocking extremely high performance from the tailless planform.

In the past, various methods have been used to move the CG in flight. One popular method is to simply connect a servo to the battery pack. Since the mass of a battery pack is relatively small in comparison to the entire airframe, it’s difficult to get enough CG movement. Tests done by Hans-Jürgen’s team, for example, show a CG movement of around 4 mm on airframes suitable for competition. Stefan Siemanns, however, has perfected a way to move the entire fuselage, thus obtaining CG movements over a 15 mm range, which is quite an improvement.

In the words of Hans-Jürgen, “Why do we use radio controls? To build constructions characterized by very high ‘own-stability’? It’s a joke! We have to be creative; fantasy has to rule our thoughts! Think about the F-16, B-2, all the modern fighters. There is no ‘own-stability,’ there is a computer! This is the future of model sailplaning. And there is one geometry waiting for this time — the tailless glider!”

A system which integrates the power to move the center of gravity over a wide range and a method of maintaining aerodynamic stability should allow tailless planform performance to far surpass and remain permanently ahead of that of conventional tailed designs.

As noted earlier, Hans-Jürgen has a number of projects in which he is currently involved. We will attempt to keep readers of this column informed of the progress and results of these various endeavors.

A Review of the “ZAGI” a competitor for slope combat

Trick R/C, operated by Jerry Teisan, produces several tailless gliders for combat on the slope. In addition to the “ZAGI-LE,” probably the most popular slope combat ’ship available today, Trick R/C produces the “B-2A” in silhouette scale and the “Razor,” which has a swept wing planform and sports winglets.

THE KIT

Our Trick R/C “ZAGI” came to us in a plain brown box measuring 28"x12"x4". It was nearly filled with components. A large plastic bag held the two wing halves still in their foam core beds, the pre-cut 1/8th inch balsa elevons, a complete hardware package, and the 12 page instruction manual. Outside the plastic bag floated a lead weight and a roll of packing tape. Although free to bounce around inside the box, neither of these objects seemed to have created any havoc with the foam cores.

The wings were impressive. The “ZAGI” has a wing span of 48", so each core is over two feet long. The airfoil Jerry uses is 12% thick, which makes the wings nearly two inches from top to bottom. The balsa elevons were not spongy, neither were they of such high density that they were overly heavy. The hardware package included pushrods, clevices, and control horns. The lead weight used for achieving the proper CG location weighed about 1.5 ounces. The packing tape was standard fare.

REQUIRED TOOLS

Anyone who has previously built an RC airplane more than likely has all of the tools needed to build a “ZAGI.” A sanding block with sandpaper of 150 to

320 grit is used to clean up the foam cores. Five minute epoxy is the only adhesive required. An X-Acto type knife and/or a Dremel tool makes easy work of cutting recesses in the foam. A ruler and a triangle or square with a 90 degree angle are used to place and align components. A round barreled pen or pencil is used to both mark the foam prior to cutting and as a fulcrum during balancing.

CONSTRUCTION

Cutting the “ZAGI” foam cores with a hot wire has got to be problematic because of the high taper ratio of the wings, yet the panels smoothed out nicely with a light application of sandpaper. We used the beds to support the wing panels during this process as well as while we rounded the leading edges. Once the wings were smoothed, everything, including the beds, was thoroughly vacuumed.

In order to have a firm fixture for construction, the two top beds are attached to each other using five minute epoxy; same for the two bottom beds. After placing waxed paper on the center line of the lower bed, the two wing halves were brought together and their fit checked. A mixture of epoxy and micro-balloons was applied to the root of each wing panel and the two parts brought snugly together using the bottom beds as a jig.

Believe it or not, when the epoxy has hardened, it’s time to start covering! Long strips of packing tape are layered in slightly overlapping fashion from the trailing edge to the leading edge. We placed the tape strips down while alternating between the left and right wing panels, thus making sort of an overlapping weave at the center of the wing. Top surface first, then bottom.

Once the wing is covered, it’s time to take care of the elevons. The instructions say to cover the elevons with tape and then use tape to construct a hinge. This turns out to be a LOT of tape, which equates to a LOT of weight, much of it excess. The “ZAGI” is so short coupled that an extra ounce at the trailing edge required four ounces in the nose to compensate. If we had it to do over again, we’d consider putting a couple of coats of dope on the elevons and using the tape only to construct the hinge.

Now that the airframe is complete, it’s time to install the radio gear!

RADIO INSTALLATION

All of the main radio components are installed by forming a hole of the appropriate size at a predetermined location. Receiver, battery pack and servos are all press fit into the airframe. If done properly, this is very secure and affords quite a bit of protection.

Before laying out the location of the various components of your radio system, you'll need to know which of three radio installation procedures will be followed. This is because Jerry includes detailed directions for installations using transmitter based mixers, for those using add-on mixers at the receiver (Christy mixer or equivalent), and for those utilizing the Du-Bro mechanical mixer. We're using our trusty JR Century VII system which has both v-tail mixing and aileron-rudder mix. These two options, used together, allow us to fly elevon controlled aircraft off the single right hand transmitter stick.

Servo location is the same if mixing is at the transmitter or receiver, while the Du-Bro mechanical mixer requires servos be mounted in different locations. Locations of the battery pack and receiver are based on control setup, but are easily laid out.

Once locations of the components are marked on the foam, it's a simple matter to carve out a properly shaped receptacle in the foam. We cut the foam into small squares using an X-Acto blade, then cleaned up the recess with a small router blade mounted on a Dremel tool. It's important that everything fit snugly. We didn't run into any problems, but you can always fill a too large hole with balsa scrap.

The antenna and the wiring to the servos is run through shallow channels carved in the foam. We used an X-Acto blade to cut an initial guide groove, then ran the Dremel router beneath the surface of the foam while following the guide groove.

The lead nose weight is the last thing to be embedded in the foam core. The control horns are mounted on the elevons. A pushrod connects each servo to its respective elevon.

Having everything out in the open is a unique visual experience, and utterly efficient for use in slope combat.

FINISHING CONSTRUCTION

Just two things left to do.

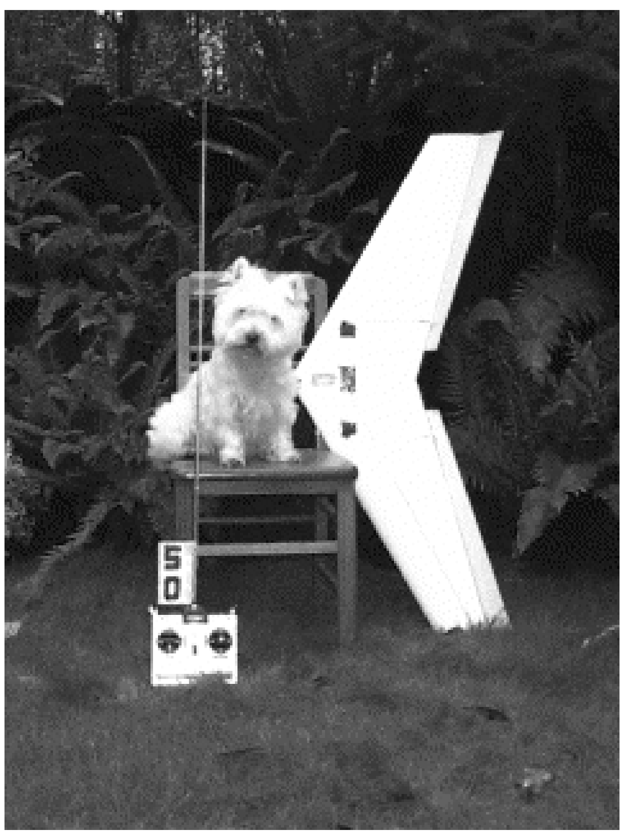
First, the elevons are set up for aerodynamic trim. This consists of using a straight edge to align the elevons with the bottom surface of the wing trailing edge.

Second, the location of the CG is marked on the bottom surface of the wing using a triangle or square, and that round barreled pen or pencil listed under "tools needed" is then lightly taped across the centerline right over that mark. The wing is placed right side up on a flat surface and weight is added to the nose in the area of the already existing lead nose weight until the complete “ZAGI” momentarily balances on the pencil. Because we fully taped the elevons, we had to add quite a bit of weight to the nose of our “ZAGI.” As mentioned before, we will attempt a lighter finish on the elevons when we build another.

An optional step is painting. If you are to be involved in a slope combat environment, be sure to follow through on this. Identification of your ‘ship in the heat of battle is imperative! It’s also beneficial to use a different color for the top and bottom of the wing to aid in orientation under tense conditions.

<u>FLYING</u>

Due to uncooperative weather during late summer, our flying experiences with our “ZAGI” were limited to some tosses off our deck and over the field below. The “ZAGI” flies fast, rolls quick, and exhibits rapid pitch response. These are all good characteristics. Recovery from strange attitudes is easy due to the its inherent stability.



Hobie Dogg, our West Highland White Terrier,
and the “ZAGI”.

The instructions cover repair of major dings to the leading edge. It’s just a matter of cutting out the dinged section, gluing in a styrofoam block, sanding the block to shape, and retaping. Since our field is filled with man-eating blackberry bushes and a grove of young alder, we got to experience some minor dings to the leading of our “ZAGI” wing during our experimentation. Most of these disappeared overnight, just as the instructions promised. The others, all minor, have not been repaired as yet because they don’t seem to be adversely affecting flight performance.

CONCLUSION

The “ZAGI” builds incredibly fast - three hours max. We counted the curing time of the epoxy for this total, but not the time spent swinging various parts around our heads while making airplane noises. The resulting airframe is nothing if not downright cute. It is robust, flies great, and is ultimately portable. With some carefully chosen paint schemes, this little goblin has great potential as an art form.

Our “ZAGI” was produced by Trick R/C before the advent of the “ZAGI-LE,” and so is composed entirely of white styrofoam. The LE designation comes from the use of expanded polypropylene (EPP) foam on the leading edge of

SPECIFICATIONS		
	“ZAGI”	“ZAGI-LE”
Wing span	48"	48"
Construction	2 lb. white foam throughout	2 lb. white foam & EPP leading edge
Wing area	2.83 sq. ft.	2.83 sq. ft.
Airfoil	Zagi 12/5	Zagi 12/5
Weight	16 oz.	23 oz.
Wing loading	5.65 oz./sq. ft.	7.77 oz./sq. ft.
Required radio	2 channel with electronic or mechanical mixer	2 channel with electronic or mechanical mixer
Price	No longer available	US$45 plus US$6 P&P

the wing. EPP foam is nearly indestructible; huge dents immediately spring back to their original shape.

The EPP foam leading edge brings the overall weight of the "ZAGI-LE" to 23 ounces, and the wing loading up to a bit over 7.7 oz./sq.ft. The "ZAGI-LE" will fly in winds of 7 to 50 m.p.h. Jerry has flown his "ZAGI" with an additional 16 ounces of lead right on the CG, effectively doubling the original design wing loading!

Jerry has also added winglets to the "ZAGI-LE." These seem to improve performance, but can get knocked off in combat, leaving the aircraft nose heavy and more susceptible to hits from other combatants.

Due to the overwhelming acceptance of the "ZAGI-LE," the original "ZAGI" is no longer in production. The "ZAGI-LE" uses the same construction techniques and is available in six colors. It sells for US$45.00 plus $6.00 packaging and shipping. Trick R/C, Jerry Teisan, 938 Victoria Ave, Venice CA 90291. To order call (310) 301-1614. On the World Wide Web, <http://www.zagi.com>; E-mail to Zod@zagi.com.

Buy it, glue it, tape it, chuck in your radio and fly it! What a kick in the head!

Those EH Sections Again!

Over the last few weeks we've received a number of requests from readers of this column, and visitors to our web site, for airfoil recommendations. Here's a partial list of the specific cases:

- A delta planform used for slope flying is currently using a symmetrical airfoil, but performance in light lift leaves something to be desired. What airfoil should be used to improve light lift performance, while retaining the near zero pitching moment of the symmetrical section currently being used?
- A PSS Me-163 "Komet" with a conventional cambered airfoil requires several degrees of twist to provide stability. Removal of wing twist would improve performance and allow a more realistic appearance. Is there an airfoil available which will allow this?
- A swept wing planform of roughly two meter wing span is to be used for thermal soaring. The performance must be rather docile, as the resulting 'ship will be used as a tailless trainer. What airfoil will provide good stall characteristics and a stable platform?
- A high performance swept wing tailless glider for the 60 inch slope racing class is being designed. The designer is looking for a low drag section which will require very little twist for stability. No airfoil had been chosen when this request was received.

It was no surprise to us that we were able to recommend one of the EH airfoils for each of these applications.

In the first case, the delta, any of the EH sections can be used as nearly a direct replacement for the symmetrical section. This is because all of the EH sections have pitching moments very near zero. As cambered sections, however, they are capable of producing substantially more lift than the symmetrical sections they replace. Substituting a cambered EH section for the symmetrical section would improve light lift performance.

For the ME-163 "Komet," which could benefit from a reduction in wing twist, the EH sections again are useful. Using a section with a lower pitching moment and a smaller zero lift angle would allow removal of nearly all of the wing twist while still maintaining a good degree of stability.

In the third case, the swept wing tailless trainer, the EH sections are an attractive choice because of their excellent stall characteristics. A larger than usual amount of twist might be useful in this instance as it would allow the CG to be placed somewhat further forward, making a more stable platform.

Lastly, for the slope racing enthusiast, the low drag EH sections can be thinned to a moderate degree for further drag reduction without fear of losing the positive characteristics outlined above. The EH 1.0/7.0, a thinned version of the EH 1.0/9.0, was used with great success on the “Joined 1,” the near record breaking model described in the April 1996 issue of *RCSD*. It serves as an example of what can be done in this regard.

Coordinates for the various EH sections have been printed within the pages of *RCSD*. The EH 1.0/9.0, 1.5/9.0, and 2.0/10.0 were covered in the November 1990 issue, the EH 2.0/12.0 and 3.0/12.0 in the December 1992 issue. Both of these columns are available in “On the ’Wing... the book.” Information on the EH 0.0/9.0 was published in the January 1996 issue, and is available elsewhere in this book. Coordinates for all of the EH sections mentioned in this column are also available on our web site at <http://www.halcyon.com/bsquared/EH.html>. Coordinate tables, regardless of the source, always include the pitching moment and zero lift angle for the described section. These two aerodynamic characteristics are needed when designing a tailless planform by means of the Panknin code.

With all of their positive characteristics, the EH sections have proven themselves to be excellent choices for many tailless applications. Despite new airfoils appearing on the scene, the EH sections will be attractive alternatives for tailless aircraft designers for a very long time.

A Comparison of Two Tailless RC-HLGs

We recently received a packet of information from Andrew MacDonald, our Australian correspondent, in which was contained information on Hans-Jürgen Unverferth's latest creation, a tailless RC-HLG. At about the same time, Herk Stokely sent us photos and basic planform measurements for his latest RC-HLG, which is tailless as well.

As both of these aircraft were designed and built within roughly the same time-frames, we thought *RCSD* readers would like to see a comparison of the two gliders.

We'll start with Herk Stokely's creation. Herk's 'ship has a tapered wing and eight degrees of washout. The relatively large amount of washout is dictated by the airfoils used, a thinned SD 7037 at the root and a thinned SD 8020 at the tip. Pitching moment is determined by camber line shape and not by thickness, and it takes a lot of twist to overcome the strong negative pitching moment of the SD 7037.

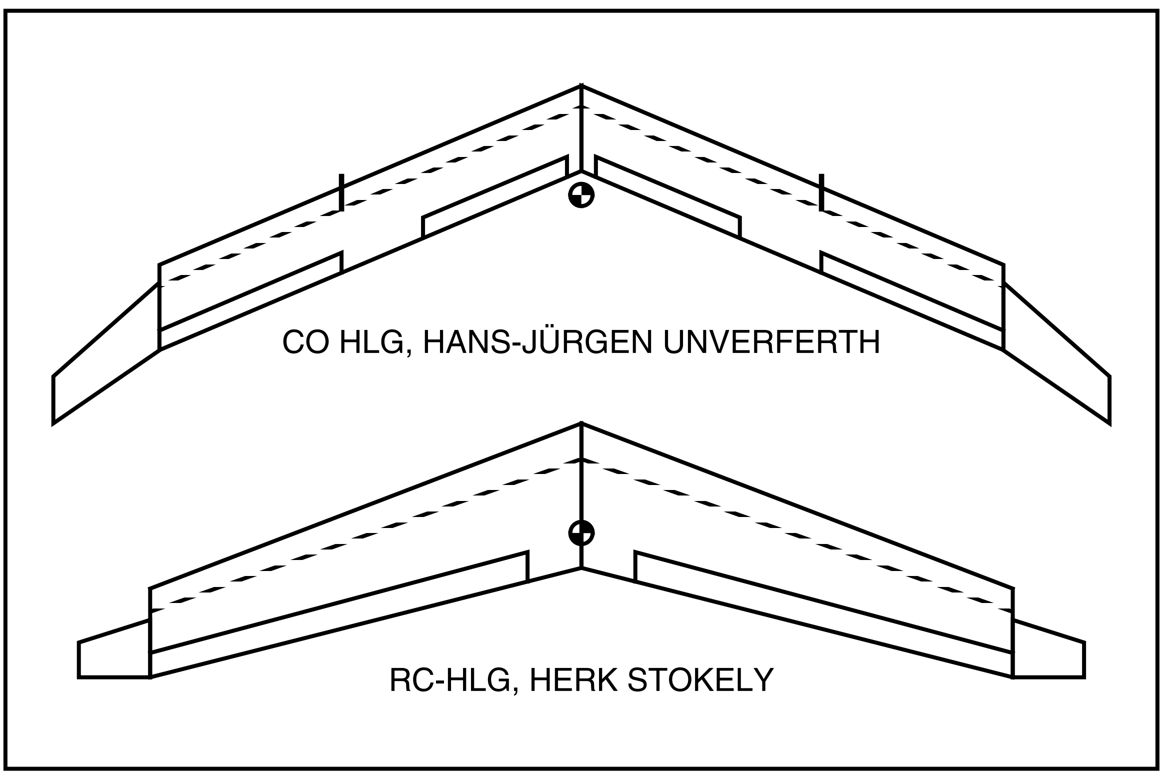
Hans-Jürgen's design, in contrast, utilizes a constant chord wing and four degrees of washout. The airfoil used, which bears the designation RS004A, is essentially a slightly thinned version of the RS001 described in a previous column. The pitching moment of the RS004A is not so large as the SD 7037. The CO HLG also uses flaps. This option allows slower speeds, very tight turns, and exceptional control during landing approaches.

The pictures of Herk's design in the February 1997 issue of *Flying Models* magazine show some very light carbon fiber reinforcement, specifically on the upper surface. There is also a carbon fiber arrow shaft spar system. Two servos are used. The CO HLG, on the other hand, has spars with carbon fiber caps, and the wing itself is of high density foam. This design uses four servos — two in each wing. These factors dramatically influence weight and wing loading, so while Herk's design is very light and has a wing loading under four ounces per square foot, Hans-Jürgen's CO HLG is heavier and, with less wing area, it's wing loading turns out to be more than double that of Herk's.

Herk has been throwing and high-starting his 'wing, while Hans-Jürgen has been throwing and winching his into the air.

Herk is very pleased with his RC-HLG design. It is stable, capable of being flown by near-novice pilots, and competitive with conventional tailed designs in the contest environment. Hans-Jürgen is very happy with his CO HLG, also. It exhibits good dead air time from a hand launch (50 secs.), and the flaps greatly expand the speed range and help with precision landings. Wing fences help maintain aileron control, and turns are said to be incredibly tight with this machine. The report we received from Andrew indicated Hans-Jürgen had been flying only the CO HLG for the last five weeks, and he is now seriously considering a second construction with a Speed 400 motor installed! CO HLG appears in the January 1997 issue of *Aufwind*, the German aeromodelling magazine devoted to sailplanes.

An included table details the dimensions of the models and shows the similarities and differences of these two designs. We hope this information is of interest and use to *RCSD* readers planning to design, construct, and fly their own tailless RC-HLG.

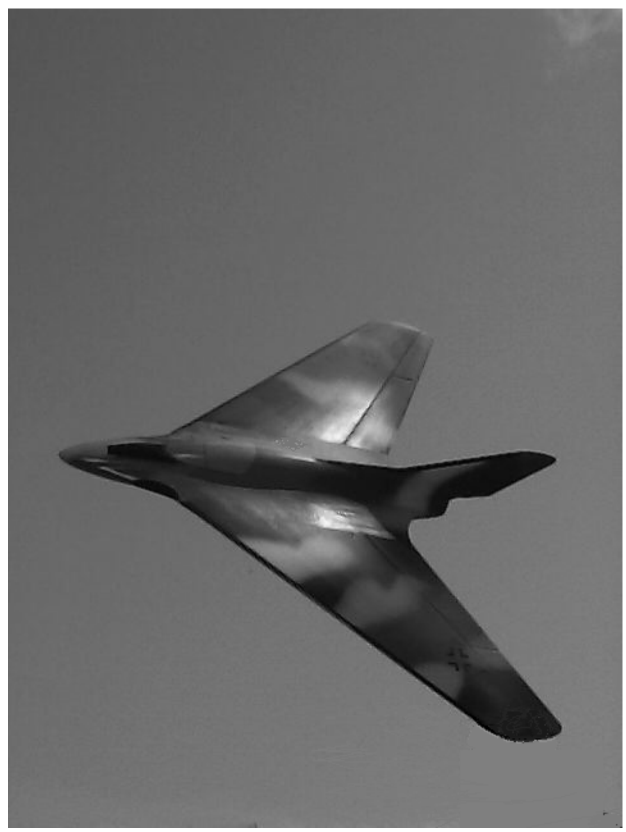


DIMENSION	DESIGNER	
	Herk Stokely	Hans-Jürgen Unverferth
Span	60", 1524mm	58.5", 1485mm
Chord, root	10", 254mm	6", 153mm
Airfoil, root	SD 7037 (7.5%)	RS004A (9%)
Chord, tip	6", 152mm	6", 153mm
Airfoil, tip	SD 8020 (6%)	RS004A (9%)
Sweep angle	22.5° at LE, 20.85° at $c_{0.25}$	24.9 degrees
Wing area	480 in^2, 30.97 dm^2	351 in^2, 22.645 dm^2
Washout	8 degrees, linear	4 degrees, from half semi-span
CG location	7.7", 195mm, behind apex	7.7", 195mm, behind apex
Elevon size (l, w_r, w_t)	26", 2", 1.7" 660.4mm, 51mm, 43mm	12.5", 1.2", 1.2" 317.5mm, 30mm, 30mm
Flap size (l, w_r, w_t)	flaps not used	7.7", 1.2", 1.2" 195mm, 30mm, 30mm
Fin size (h, w_r, w_t, sweep)	5", 4", 2.5", 1.5" 127mm, 102mm, 63.5mm, 38mm	7.3", 4.7", 3.15", 5" 185mm, 120mm, 80mm, 126mm
Construction, wing	foam and fiberglass, with CF arrow shaft spar	foam and fiberglass, with 7mm x 1mm CF spar system
Construction, winglets	1/16" balsa sheet	unknown; could be made of balsa sheet
Weight	11.8oz., 334.5g	17.6oz, 500g
Wing loading	3.54 oz/ft^2, 10.8g/dm^2	7.22oz/ft^2, 22.1g/dm^2
Battery type	125mah	500mah
Controls	elevons only	elevons and flaps
Notes	Extremely easy to fly; has very good performance	Uses wing fences and flaps; is capable of very tight turns

Herk Stokely's RC-HLG

The Messerschmitt Me P.1111 for P.S.S.

Some years ago we purchased a copy of Wooldridge's "Winged Wonders," a historical overview of the development of the Northrop flying wings. "Winged Wonders" includes a large amount of information about other tailless designs, thus enabling the Northrop efforts to be appreciated in proper perspective. As many readers will understand, we found quite a few aircraft which we would eventually like to model. One design, however, was so impressive we placed it at the top of our mental priority list of models to be built.



The design which so captivated our attention was the Messerschmitt P.1111, the Messerschmitt Design Bureau entry into a 1944 design competition. The P.1111 was to be a tailless aircraft with wings swept back at 45 degrees and a single swept back vertical fin and rudder. The pilot was seated in a pressurized cockpit. Armament consisted of four MK 108 30mm cannon; two in the wing roots and two in the nose. The wing span was to be slightly more than nine meters (30' 1"), the length a bit less than nine meters (29' 3.4"). Performance was calculated to give a top speed of well over 600 m.p.h. The P.1111 is similar in design and projected performance to the DeHavilland DH 108 which successfully flew in 1946.

Design

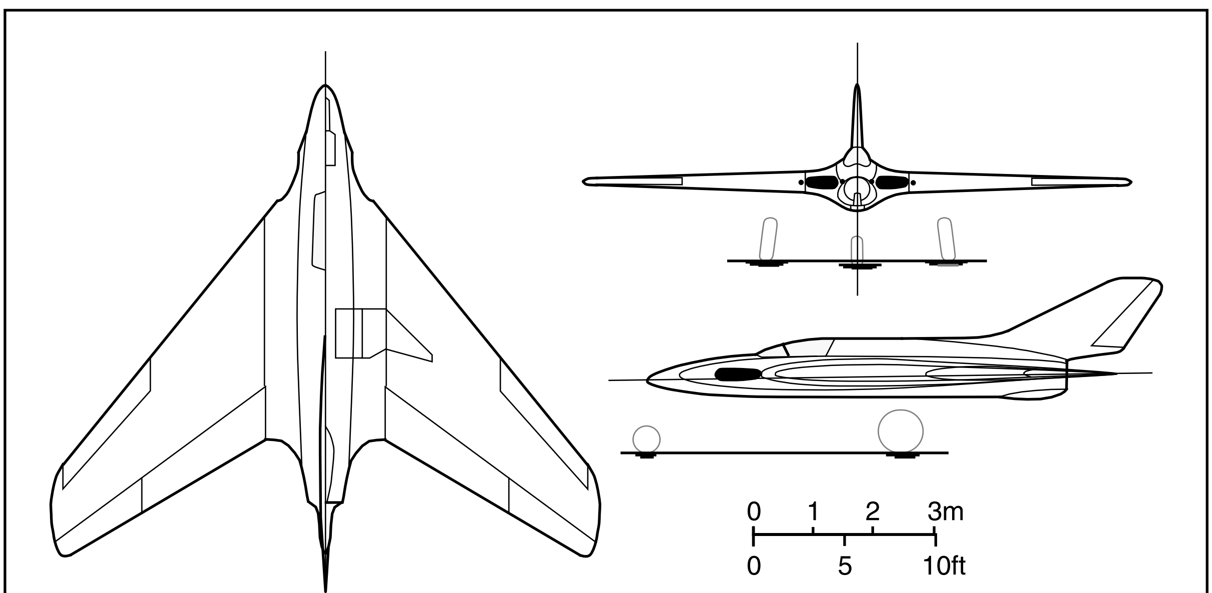
A few days after first seeing the P.1111 three-view, we concluded a model of reasonable size could be built from a small amount of foam using a minimum of internal structure. Covered in fiberglass, the resulting model would be relatively light weight, yet because the overall design is so streamlined, model speed would be sufficient to offer acceptable penetration on a wind swept slope.

Because of the projected light weight of this model, we decided to use a symmetrical Quabeck section for all of the flying surfaces. As control surfaces cover the entire trailing edge of the wing, it was an easy matter to hook up two servos in each wing; one servo to control the elevon, the other to operate the inner flap. The trailing edge of the wing could be used to impart the necessary positive pitching moment for stable flight.

Sketches were drawn for a four foot span model. Templates were made from light plywood so the fuselage could be cut from both a top view and side view. Shaping the foam to a three dimensional form would then a relatively easy task. A large opening was planned for the bottom of the fuselage so that the receiver and battery pack would be easily accessible.

Construction

Cavities were cut into foam sheets to accommodate the radio gear and allow for access. These layers of foam were tacked together and cut out to the general P.1111 fuselage outline using the two precut templates. The fuselage was then shaped as planned. Wings and vertical tail were cut from foam using a long hot wire, and a single template through a pivot point. Channels



Messerschmitt P.1111

were cut into the wings and fuselage to accommodate the servo wires and antenna. The resulting shaped parts — fuselage, two wings, and vertical tail — were glued together and the entire model covered in light fiberglass.

After the epoxy cured, we cut out the control surfaces, installed balsa edges to the trailing edge of the wings and the leading edge of the control surfaces. Small nylon Du-Bro hinges were used to reattach the control surfaces to the wing. Cavities for the four servos were then carved in the bottom of the wing and micro servos press fit into place. We also freed the belly hatch, completing construction.

Bill and the Messerschmitt P.1111
The central control surfaces have been locked in neutral and the servos removed, as best performance was found to be with elevons alone.

Flying

First flights of our P.1111 were at one of the Richland Slope Scale Fun Fly meets. We trimmed the inboard flaps and outboard elevons with a small amount of reflex, assured ourselves the CG was a bit forward of its predicted eventual location, and promptly chucked it off the edge. As anticipated, it flew out over the valley making good headway against the stiff wind. It was immediately obvious, however, that the small amount of reflex trimmed into the inner flaps was more of a detriment to performance than anything else. A simple flick of the two position flap switch on the transmitter retrimmed the inner flaps to neutral, and the P.1111 leaped forward.

Fine tuning of control surface throws and elevon reflex tweaked performance further. Roll response was too sensitive, so we set the aileron dual rate to 50%, while elevator function remained at 100%. With reduced reflex, we were able to move the CG back to near the predetermined position. The resulting flights were quite beautiful, with very well coordinated turns, despite lack of a rudder, and large loops. The P.1111 looked incredibly realistic in the air.

Suggested Modifications

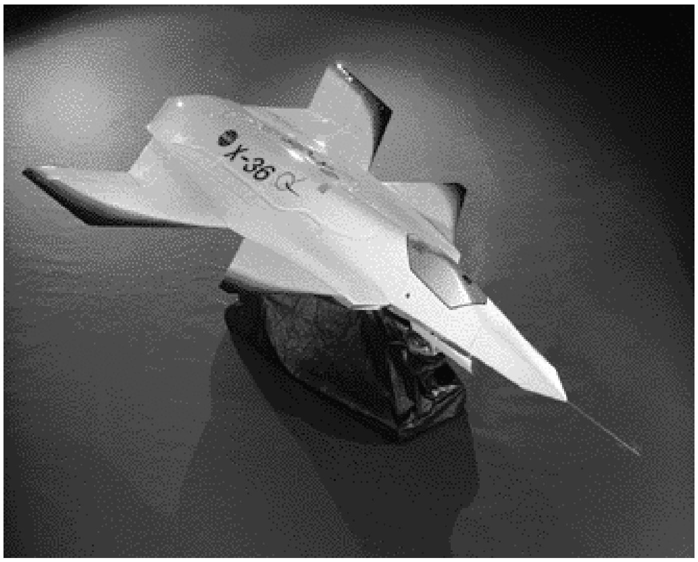
We designed and built our model before we became familiar with the EH series of airfoils. Were we to build another we would certainly substitute a thinned EH section for the Quabeck airfoil we originally used. A small amount of washout, just a fraction of an inch at the wing tip, would be more efficient than trimming with the elevons, but those who enjoy good inverted performance might want to forgo that modification. The inboard control surfaces, which never proved beneficial on our model, could be eliminated. The resulting two servo control system, composed of an elevon on each wing, works extremely well on this planform, despite its simplicity.

Given time, and some positive feedback, we may eventually formalize those plans we drew, incorporate the above noted changes, and make them available through Cirrus Aviation Ltd.* Yes, this is a call for positive feedback!

Wooldridge, E.T. Winged Wonders; *The Story of the Flying Wings.* Washington, D.C.: Smithsonian Institution Press, 1988.

* Cirrus Aviation Ltd., Harry Volk, P.O. Box 7093 Depot 4, Victoria B.C. V9B 4Z2, Canada.

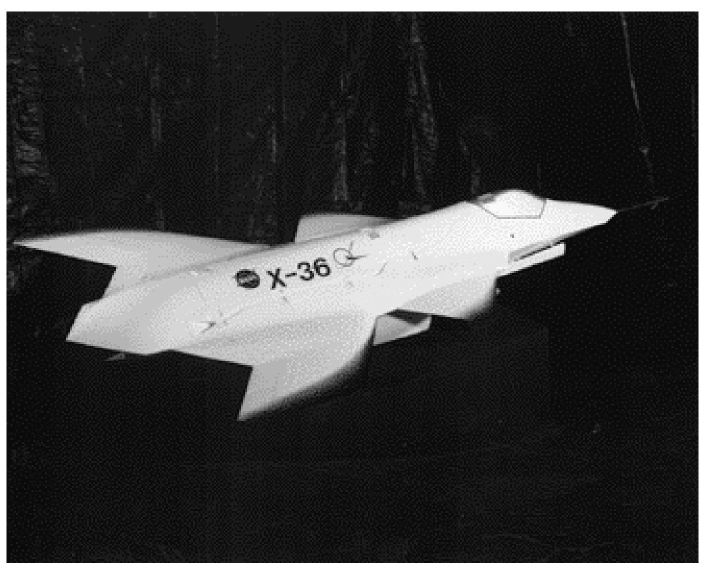
The X-36 “Backgrounder” Tailless Research Aircraft



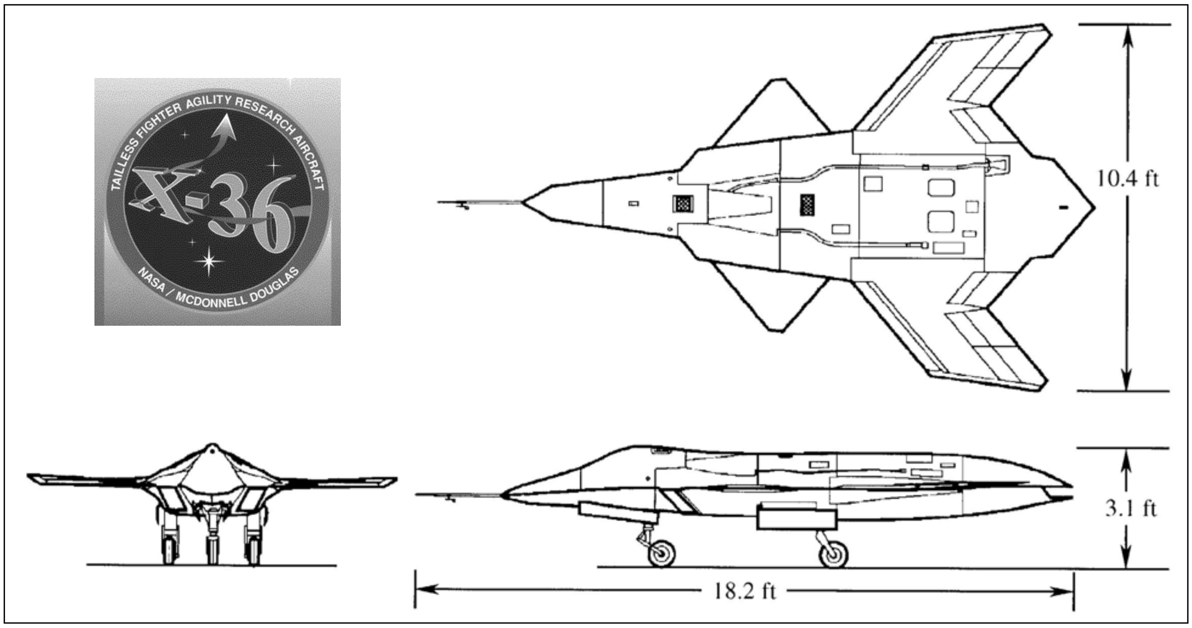
All you modelers of tailless planforms who have been asking about incorporating helicopter gyros to control yaw now have a platform to test out your ideas!

The X-36 “Backgrounder” was developed jointly by McDonnell Douglas and the National Aeronautics and Space Administration over a 28 month period, at a cost of $17 million. Rollout of the 28 percent scale X-36 at McDonnell Douglas Corp., St. Louis, took place on 19 March 1996. A six month testing program, consisting of 25 flights, was scheduled to begin that summer. High speed taxi tests were done in October.

The “Backgrounder” is considered to be a tailless design, as it has no vertical or horizontal tail surfaces. The canard surfaces are apparently not moveable but do control airflow over the wing at very high angles of attack — up to 35 degrees.



Yaw and pitch control are provided by split ailerons and thrust vectoring in this powered model. The result of this novel design concept is an airframe which is lighter and has less drag than conventional aircraft of the same size, with increased range as the result. It is anticipated that



substantial increases in maneuverability andsurvivability will also be realized, together with a very small RADAR signature.

Manufactured in McDonnell Douglas Phantom Works, the X-36 is an example of rapid prototyping capabilities and was intended to demonstrate new technologies at far less cost than a full size manned aircraft. The subscale X-36 is remotely piloted through a HUD (Head Up Display) system. A video camera in the aircraft allows the pilot to fly from a ground based virtual cockpit.

The airframe of the X-36 is of machined aluminum, the skins are of carbon and epoxy (non-autoclaved). The X-36 is stressed for 5 g's. With a maximum speed of Mach 0.6, an approach speed of 110 knots, and the high maximum angle of attack, flight performance should be quite exciting. The aircraft weighs 1,300 pounds fully fueled and is 18.2 feet long, 10.4 feet wide, and 3.1 feet high with landing gear extended. A Williams Research F112 engine provides 700 pounds of thrust.

The X-36 should make a good PSS subject. We are sure some enterprising modeler will take advantage of the current state of electronics and include not only a helicopter gyro, but also an onboard video camera. This could be set up to mimic the integrated remote control system used by NASA on the original. We would very much like to hear from anyone modeling this "model," particularly if such technologies are included.

Resources:

The 3-view and photographs included in this column are courtesy of McDonnell Douglas Corp. via the X-36 rollout web page at <http://ccf.arc.nasa.gov/dx/basket/storiesetc/X36pixjo.html>, and NASA Dryden Flight Research Center at <http://www.dfrc.nasa.gov/PhotoServer/X-36/contactSmall.html>.

X-36 “Backgrounder” undergoing high speed taxi tests

Penumbra.4 thermalling over the eastern slope at 60 Acres.

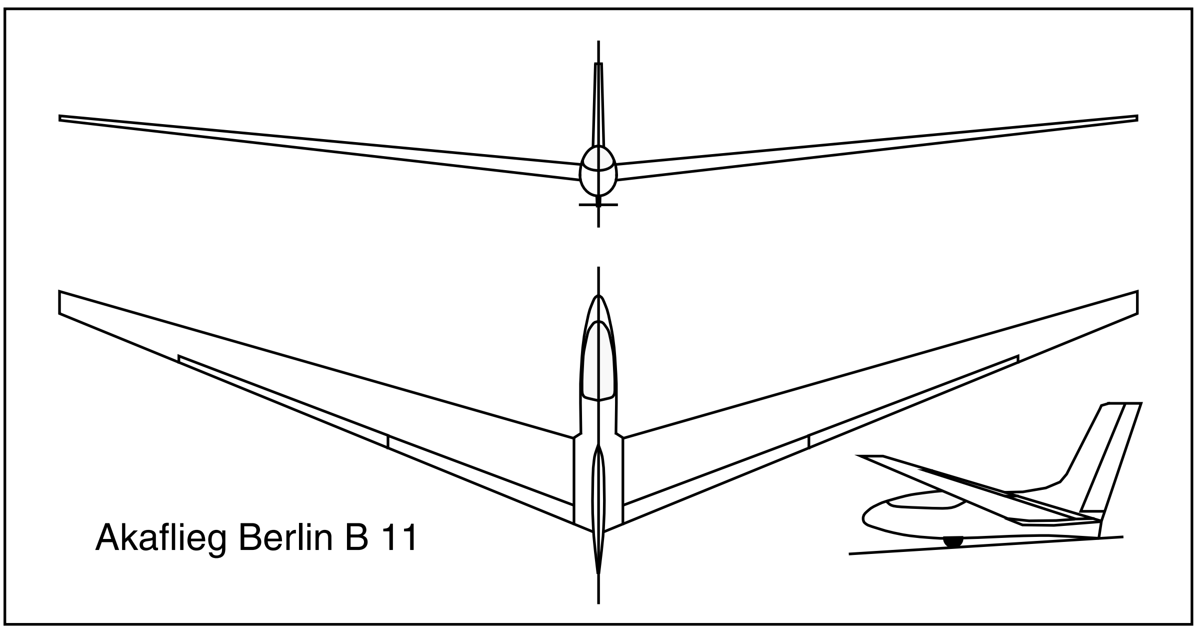
Akaflieg Berlin B 11

The August 1962 issue of *Interavia* contained a wonderful article on sailplane construction[1]. The multi-page article, which included a number of photos and diagrams, together with an extensive table of data for many sailplanes, outlined then current trends in construction technologies. Plastics, fiberglass and epoxy were just coming into widespread use at the time.

Perhaps the most fascinating glider depicted was the Akaflieg Berlin B 11, a high aspect ratio tailless design with forward swept wings.

Despite the structural difficulties and lift distribution problems associated with forward swept tailless designs, there are a few advantages to the planform, particularly for full size aircraft:

- A forward swept wing allows the pilot to be placed very close to the CG, while at the same time preventing the wing from obstructing the pilot's view of the ground. This is an important consideration during landing.
- Sweep is related to effective dihedral. Sweep back increases effective dihedral as C_L increases, while sweep forward does just the opposite. This



Akaflieg Berlin B 11	
Dimension	Value
Span	17.325 m, 56' 10"
Wing area	15.8 m^2, 170 ft^2
Taper ratio	0.25
Sweep angle, c/4	18 degrees
Maximum weight	321 kg, 708 lbs.
V, landing	63 km/h, 39 m.p.h.
V, optimum glide angle	80 km/h, 50 m.p.h.
V, maximum	155 km/h, 96 m.p.h.

means swept forward wings need more dihedral. The benefit here is that the wing tips are always high off the ground, free of obstructions.

- Swept back wings tend to drag wing tips during landing, when the angle of attack is high. This tends to drive the designer toward reducing the sweep angle, thus requiring more aerodynamic wing twist to maintain stability, or increasing the dihedral angle, which leads to too high an effective dihedral angle in thermal turns and other high C_L conditions.
- Forward sweep inhibits tip stalling because the air flow tends to move toward the fuselage rather than toward the wing tips.

The Akaflieg Berlin B 11 went through a formal design process, and wind tunnel testing of a two meter span model was carried out[2], but we know nothing more about this intriguing design. We do think a model would be beautiful in the air, and would very much like to hear from anyone with additional information.

References:

1. From String Bags to Super-Kites, Trends in Sailplane Construction Today. *Interavia*, August 1962.

2. TWITT Newsletter. Andy Kecskes, Ed. No. 26, August 1988.

Dennis Weatherly's "JackWabbit"

This month's column describes a reader's tailless creation. Dennis Weatherly first approached us concerning information on one of the EH sections for a larger tailless design, but his smaller testbed so impressed us we just had to devote a column to it. Here's what Dennis has to say about his latest flying machine...

"First, a big thank you for your web page and for providing a source of information regarding flying wings. I have always been fascinated by them. I've only built one so far (an RCM Little Plank) but that is changing soon.

"A friend has helped me to design a swept wing that I will power with an electric ducted fan system. The proposed model will use an EH 2.0/10.0 airfoil, 14" root chord, 10" tip chord, 72" span and three degrees of twist. Projected weight is about seven pounds. Power will come from a WeMo Tec RK740E fan unit (4.2" diameter) driven by an Aveox 1412/4Y motor on around 28 cells. It should be exciting!

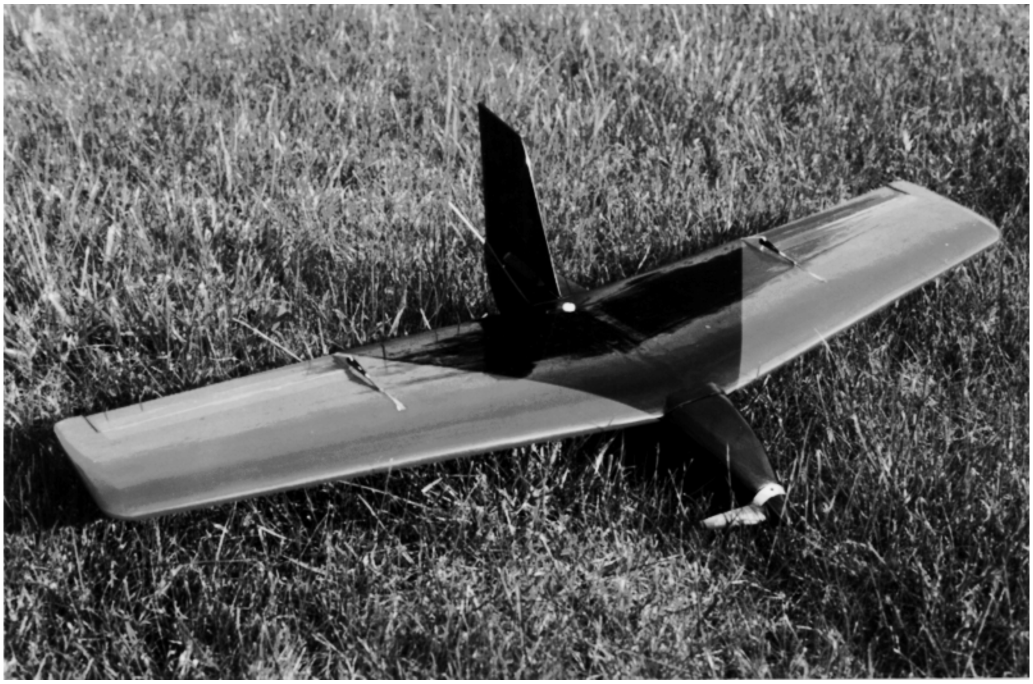
"Since I am a computer driver by trade I was interested in the program (my friend) used to determine the twist. He pointed me at your web page where I downloaded the Panknin Twist program. It works fine under QBasic and Windows 95..."

A few days later, Dennis wrote...

"To prove to myself that I could design and fly a 'wing, I shrunk the proposed big jet down to Speed 400 electric size. The resulting model shared the same taper ratio and sweep in a 30" span, 7" root chord, 5" tip chord and 180 square inch package. I used a stubby box fuselage and a single vertical fin, with the fin LE against the wing TE. Airfoil is the EH 2.0/10.0 with three degrees of twist. Ready to fly weight is 15 ounces.

"Only I goofed when I cut the cores and I ended up with 20 degrees of total sweep, rather than 20 degrees per panel. So it was more like a plank than originally planned. I plugged the numbers into the Panknin Twist program and got a CG of 2.9 inches back at the root, so I started there.

"Rolf Zurcher helped me with control throws and we gave it a toss. It zoomed straight up, rolled uncontrollably as it slowed down and then dove into the



tall grass (thank goodness)! Damage was minor and quickly repaired. Rolf figured that the roll problem was adverse yaw due to the low airspeed. We moved the motor battery ahead 0.5" and tried again.

“The second flight was better. I had my hands full trying to fly the plane, find the trim knobs and get some down trim dialed in. It was pretty quick! After about a minute of this I landed for a breather and to reset the surfaces.

“The trim changes had resulted in the elevons being depressed below the wing TE, so I guess the twist was too much. With the trim dialed in and a fresh charge we launched for flight number three. Success! The little plane accelerated straight away and flew beautifully. Pitch and roll control is solid and well damped. It tracks through turns like it’s on rails. And it is really fast! Most people estimated the airspeed at over 60 m.p.h. flying straight and level. I flew it four more times at the Celebration of Silent Flight.

“A funny thing has happened since I reported my success on the e-flight mailing list; folks are contacting me as if I’m a flying wing “expert”! There are a lot of folks out there that are intrigued with them but afraid to try for fear of failure. Speed 400 sized models make great experimental tools since they are so small and cheap.

“It only took a week to design and build this little wing. My wife named it the JackWabbit. I think I’ll try to build JackWabbit 2 and get the wing sweep right this time! In the mean time I am already receiving requests for plans and wing cores for JackWabbit 1.”

While communicating with Dennis, it became apparent that the wing twist is indeed too much, despite the smaller than intended sweep angle. It appears that too large a design C_L was plugged into the Panknin program. As set up, a lower C_L is needed when powered, and thus down trim is required. If the design C_L is lowered, less twist will be called for by the Panknin program. This may necessitate some small amount of up trim when in gliding flight, but that pitch up under power needs to be eliminated from within the planform. With 20 degrees of sweep, the twist should probably be reduced to one degree.

Congratulations, Dennis, for a great looking and good performing design! And be sure to keep us updated on JackWabbit 2!

JackWabbit Dimensions	
Wing span	30" span, 7" root chord, 5" tip chord
Sweep per panel, at c/4	10 degrees
Wing twist	3 degrees (which proved to be a bit too much)
Airfoil	EH 2.0/10.0
Wing construction	foam core with l/32" balsa sheeting
Fuselage construction	balsa sheet
Power	Robbe Speed 400 6 volt motor, direct drive
Propeller	Graupner CAM 5x5 prop and spinner
Speed controller	New Creations 30 amp controller with BEC
Receiver	Hitec-RCD 535
Receiver antenna	Dean's base loaded
Battery pack	7 cell Sanyo 500AR
Servos	FMA S80 (micro); one buried in each wing panel
Ready to fly weight	15 ounces

To invent an airplane is nothing.
To build one is something.
To fly (it) is everything.

— Otto Lilienthal

Jim Keller's "Zephyrus"

The cheapest form of instant (well nearly instant) self gratification

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This month's column is written by Jim Keller of Diamond Bar, California.

Here's my story on the development of the flying wing I wrote about in RCSE and received so much mail about (approximately 20 requests for more info, specs, setup, etc.), and call the Zephyrus.

I've always been an airplane nut, starting my model building career in about 1949. I have been interested more than just mildly in flying wings for years. An early recollection during my childhood right after WW II was seeing a Northrop wing flying near the Lockheed Burbank facility.

The last few years, I have taken to designing and scratch building planes. Last year I got hooked on slope soaring, and I find every excuse in the book to leave work on time to get in some evening soaring. This is in addition to my daily jaunt to a local park near work to fly a HLG or 2m ship during lunchtime. I also leave early for work sometimes and fly a small electric planes from a park near home. Did someone say I was obsessed?

Enough digression. Recently, a regular flier at the slope showed up with a Zagi-LE. I was astonished at two aspects of the plane: it handled light lift with ease, and when the rest of us were sitting, waiting for the wind to pick up, he was flying; it also was very agile, regardless of the wind speed. That did it. All of the studying, reading and calculations for my own design had to be accelerated.

About this time, I was also doing a lot of business travel. I would sketch a wing and then make a card stock model and fly around the hotel room in the evenings I was away from home. This prepared me for the practical side of things and taught me what worked, and what didn't. I experimented with planforms, sweep angles, tip twist, elevon configurations, stability and control. It seemed the best flyers were the ones with a 23 degree sweep and full span elevons. I was performing these little experiments at fairly low airspeeds, where stall recovery could be evaluated.

The resulting planform that I present here is the best compromise of all:

Jim's daughter Colleen with the Zephyrus

- 48" wing, approximately 10% thick RG 15 airfoil, 4 degree washout at the tips
- 23 degree sweep, each wing half
- 12" root chord, 7" tip chord
- white foam cores, covered with 80# Kraft paper using 3M 77 spray adhesive, then covered with 2" clear plastic packing tape
- partial span top spar made from $^{3}/_{16}$" dowel placed in slot cut on top of wing, then filled flush with fiberglass package tape. The next version will be composite or at least partially EPP foam. The paper and tape covered foam is durable, but deforms somewhat after repeated crashes, which are inevitable for slopers. My downfall is what I call blowovers, which occur when you get the plane high, right above you at the edge of the slope and you try to turn back into the wind. The plane just blows over your head and then back into the rotor. Bummer — no control!
- full length (except for about 1.25 inches each elevon root) 1½" elevons made from T.E. stock, then shaved to match airfoil and hinged with packing tape
- center of gravity so far is best at 18% M.A.C., which translates to about 6 $^{5}/_{8}$" from root L.E. for this planform. Obviously, you either need a separate mixer in the plane for the elevons, or have a computer radio programmed for elevons (which I have). Each elevon is moved by a separate Hitec HS 80 servo. You can use full size servos, but they won't be flush in the wing. You can move them a bit inboard, but unless the elevon balsa is real stiff, you'll have flexing at speed.

- for launching, I taped a small strake under the wing near the C.G. to hold when I toss it off the slope.
- all up weight for this configuration is 14.7 ounces
- wing area is 451.5 sq. ins.
- pockets cut into the foam for the receiver and 150 mAH battery in the center of the wing, and two pockets for the servos, each mounted about 10" from root line. Servos mounted from the top, pushrods on top to protect from landing damage. I laid the radio components on the covered wing and moved them around to try to achieve good balance without adding weight. This, as I now realize, wasn't necessary, since more weight will be better in 10 m.p.h. wind.
- tiplets made from $^{1}/_{16}$" ply, roughly triangular with rounded corners, 7" long and 5" high. Securely tape to tips. Make sure these are parallel with the center line of the wing, else you'll have a yaw bias for sure, which you'll need elevon trim to correct, which means you've built in some needless drag — aspects I have identified so far.

I call the plane the Zephyrus, after the Greek god of the West wind; so named since the slope I fly on faces west, into the prevailing wind.

Design Objectives

The initial full size RC plane was built with four objectives, or requirements in mind:

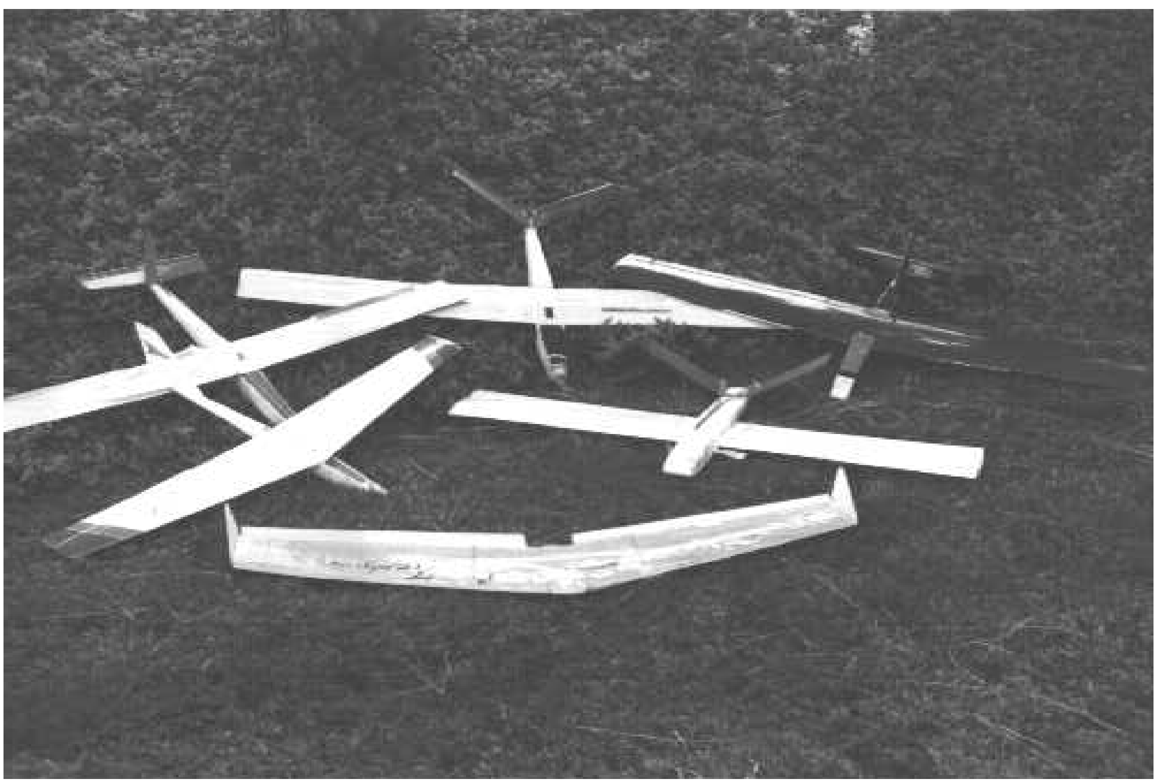
1. It had to be cheap, constructed of readily obtained and inexpensive materials.
2. It had to be durable and/or light enough to resist damage.
3. It had to be built simple and fast — I get antsy to try out something new, plus my building time has become precious lately.
4. It had to look different from the current genre of 'wings, but have a conventional (for a 'wing) planform so I wasn't outside of the range of current thinking.

To satisfy all of these requirements, I decided that brown paper and packing tape over expanded bead polystyrene (white) foam would be the cheapest and fastest approach. It would be light for a sloper, which meant that it would resist a nominal number of crashes before it became landfill fodder. Remember, this was to be a "proof of concept" model.

Construction

I cut the templates to an RG 15 airfoil, but thinned the leading edge back about an inch to allow for the extra tape I would put on the leading edge of the wing. This would allow extra reinforcement and minimize the amount of ballast up front. My next version will at least have a hardwood dowel at the L.E. to take more abuse, since the white foam deforms pretty easy. After cutting the cores, I prepared the blanks. It's important that the root and tip of each wing half be square with the transverse axis of the wing and parallel to each other to have the airfoil be true. I use 3M 77 adhesive spray to adhere the templates. The tip template was attached at a 4 degree washout position and the cores were hot wired.

After hot wiring the cores, they were glued together, making sure they were each flat and true with each other — no dihedral is built into the wing. At this point, I wrapped the wing top and bottom spanwise with one or two layers of $^3/_4$" fiberglass packaging tape. After wrapping the wing halves, I sprayed 3M 77 adhesive spray on the brown paper and the wing. I use the heavy 80# package wrapping paper you can get at most discount stationary stores like OfficeMax, OfficeDepot and Staples. After covering with the paper, I covered the paper with 2" clear plastic package tape. At this point, you're probably only 2 hours into the project, and your equivalent outlay is only about 3 - 4 bucks. At this point (actually, it should be done before covering), I sliced a $^3/_{16}$" deep groove into the top of the wing and about 15" long for a top spar made from a $^3/_{16}$" hardwood dowel. I covered the dowel and its slot with fiberglass package tape.



Jim Keller's stable, with the Zephyrus is in the front.
Half of the 'ships shown are original designs.

I used 1½" trailing edge stock for the elevons, and took a razor plane and matched the contour of the airfoil. You can easily carve the elevons from $^{3}/_{16}$" medium sheet balsa. Use your favorite method of tape hinging to attach the elevons, and the wing is essentially done, except for radio installation and balancing. Mount the elevon control horns on the top of the elevons at the point where the pushrods will attach.

The tip plates are made from $^{1}/_{16}$" birch plywood, although you could use balsa, covered with packing tape. Before mounting the tiplets, make absolutely sure that the ends of the wing tips are parallel with the centerline of the root of the wing, so as not to induce a yaw component.

Radio Installation

Radio installation is simple. Cut pockets for the receiver, battery and servos by using a sharp X-Acto knife. Cut these with care so that the components fir snugly, especially the servos, to minimize slop. Cut their location as far forward as possible, but no closer than about $^{3}/_{4}$" from the leading edge to allow for some crush space after crashes. Insert the components into the pockets and then tape over them. You can leave an inch or so of battery lead hanging out to turn off the radio, or you can use a short servo extension as an on/off switch. The pushrods for the elevons are made with Z-bends at the servo, and adjustable clevises at the elevons. If you don't have a computer radio, add a mixer and cut a pocket for it, also. When mounting the servos, angle the servo arms rearward about 30 - 40 degrees to induce differential. Tape the servo leads flat with package tape. I tape the antenna straight back and then just let the remaining 30" or so flop in the breeze.

Balancing

The balance point, if you built in strict adherence to the specs is 6.4 - 6.6 inches back from the leading edge at the root. This corresponds to about 18% M.A.C. for those aerodynamically endowed. I had to add about 2 ounces of lead to achieve this. Correct balance, of course, can be determined by hand tossing. I found that a triangular skeg made of $^{1}/_{8}$" balsa, taped along the underside of the center of the wing was very handy for hand tosses. The glide should be flat, as with a conventional plane.

Flying

This plane is intended to be a sloper, so the following is strictly for that mode. Toss the plane ahead, directly into the wind, just a tad of nose down attitude. I usually give it a little down elevon initially to gather some speed and get free of the ridge turbulence. After that, it will climb fast and then you're in for some fun. Please be advised that a characteristic of 'wings is that they will "kite" if you get a significant angle of attack. In strong wind, you need to be very quick to catch this and give it some down elevator to recover. Until I learned this, I had a number of “blowovers” where I turned into the wind close to the ridge and then had the plane blown over my head into the rotor. Play with the elevon movement to fly docile or to fly fanatically. I’ve found about ½" up and $^{3}/_{16}$" down for turns and a little less for equivalent elevator control is a happy compromise, but for the first couple of flights, set these at about half that throw.

Into the Future

With enough air time now under my belt with this plane, my next version will be fiberglass covered foam with an adjustable C.G. to experiment with stability. I will increase the weight to fall into the seven, or so, ounce per sq. ft. loading category. As the summer progresses, the wind speed increases at our slope, and the additional weight will be needed. Combat is making it’s way onto our hill, but Zephyrus, for now, is a peaceable soul, content with a combination of lazy, relaxing flight mixed with some exuberant aerobatics. We’ll leave combat for the DAWs, Foaminators, PSSs and Zagis.

Earlier, I indicated the four requirements for building this plane. If you build one too, I think you’ll see that these objectives were met, and that the fun-per-dollar ratio is pretty hard to beat. Enjoy!

Mr. Keller is an Electrical Engineer, specializing in Systems Engineering for Lockheed Martin. He has been a model builder since the 1950’s. He has built flown all forms of models from indoor to control line combat to electric flight, including the infamous Galloping Ghost RC control of the late ’60’s and early ’70’s, but now concentrates on R/C sailplanes and electrics.

Northrop Grumman B-2 "Spirit"

We are always requesting readers send in suggestions for topics for future columns, and several have asked about various aspects of the B-2 Stealth Bomber, now named "Spirit."

A query about the feasibility of building a scale model of the B-2 without an active flight control system showed up a short while ago on one of the internet e-mail groups, Doug Bullard's Nurflugel list. Al Bowers' reply to the question was fascinating not only because it disproves the general consensus about the B-2 pitch stability, but because of the methods Al employed to reach a conclusion. Here's a portion of Al's response:

"At the time of the roll-out down in Palmdale, *Aviation Week & Space Technology* ran some rather nice photos. I was still sitting in the same office with my mentor, Alex Sim. Alex and I were chatting about the B-2, and we could not decide if the aircraft were statically stable or statically unstable. Alex said the B-2 was stable and I said it was unstable (remember that the X-29 was still flying here at Dryden and I was greatly enamored with unstable aircraft at the time).

"Based on the photographs, we made a simple vortex-lattice model and estimated the CG position on the location of the main gear (typically the CG is about 15 degrees forward of the main gear for rotation at takeoff). I made the model (based on published photos) and ran the code. The B-2 is stable."

We were able to see the B-2 at relatively close range a few years ago, when one was flown into Boeing Field in Seattle. "Spirit of Washington" had its picture on the front of nearly all of the local papers, and literally thousands of people came out to see it in person at the Museum of Flight. The "Spirit of

Washington" is truly a beautiful airplane, and is one of those currently at Whiteman AFB, Missouri.

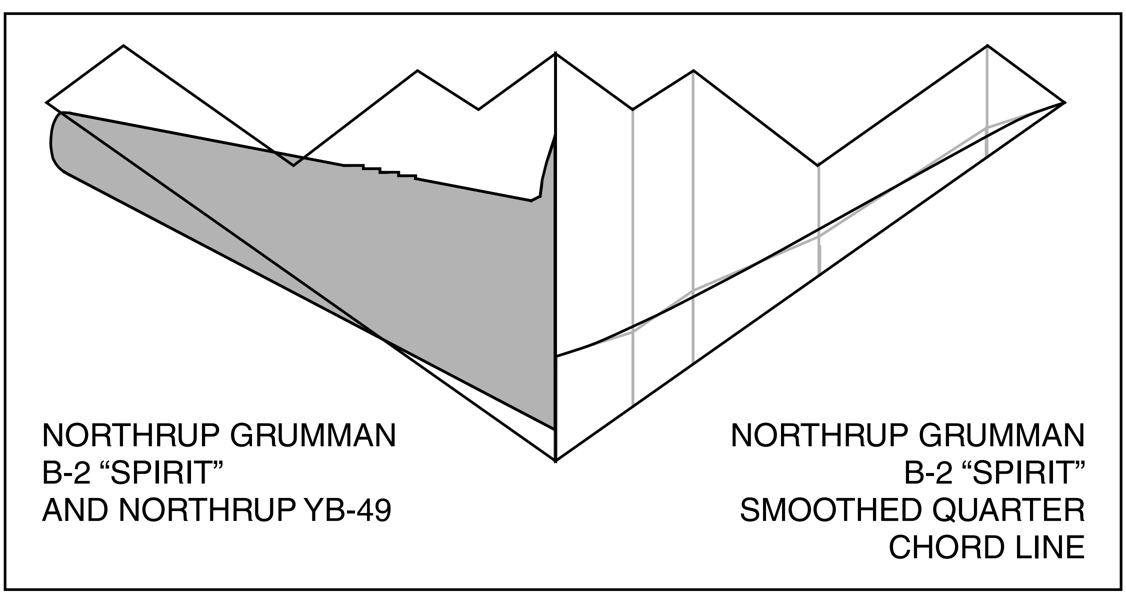
Our photographs of the "Spirit" were limited because of the curtailed number and scope of viewing sites. Still, we were able to obtain pictures of some aircraft details, and a few of our own questions about the B-2 were answered by simply being able to view the airplane first hand.

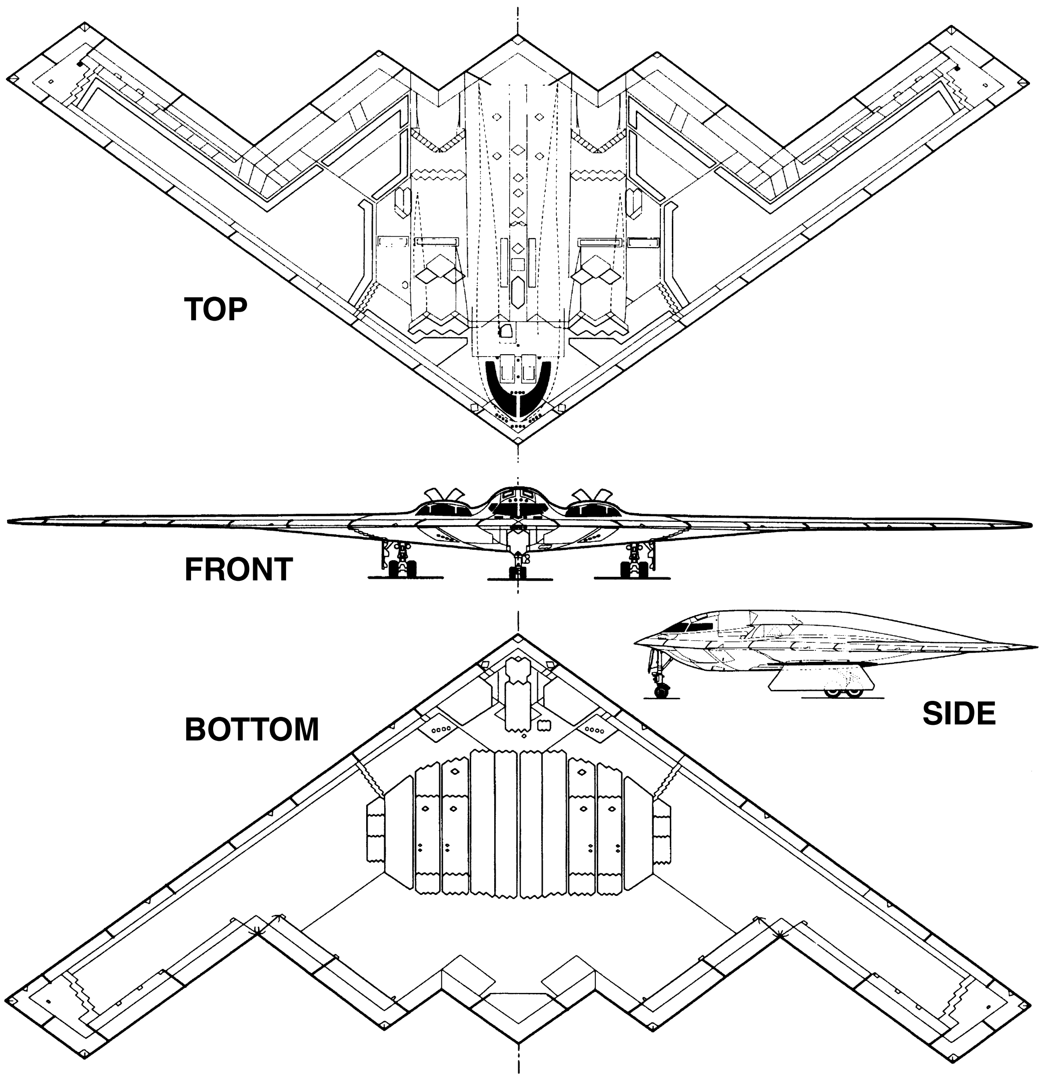
• There is a bit of twist in the outer panel of the B-2 "Spirit" wing. Since the trailing edge and leading edge of the wing actually meet at the tip, it is not easy to determine the actual amount of twist visually. However, by expanding the Air Force provided 4-view, we found it to be around two degrees.

• The wing has a very sharp leading edge, and a pronounced "droop," in the area of the fuselage — from the center line to outboard of the engine nacelles.

• The wing surface is smooth, with no creases, despite the sharp angles in the trailing edge. All of the control surfaces, on the other hand, are made from flat plates. The front view is very reminiscent of the Northrop N1M, with the lower surface of the wing forming a very wide belly.

• The B-2 has an odd shape as seen from overhead, but plotting the wing quarter chord line gave us quite a surprise. We drew up the planform of one wing and marked the chords at all of the trailing edge discontinuities. We found all of the quarter chord points, then connected them all with straight lines. Finally, we connected the midpoint of each of those line segments and used the smoothing function in our graphics program. The result is a





NORTHRUP GRUMMAN B-2 "SPIRIT"

The B-2 "Spirit of Washington" at Boeing Field, Seattle

surprisingly straight curve which arcs slightly backward initially, then forward near the wing tip. We've reproduced our graphical exercise in the included figure. That same figure contrasts the overhead view of the B-2 and the YB-49.

Specifications for the B-2 (and the YB-49) are shown in the included Table. About the only similarity between the B-2 and the Northrop YB-49 is they share the same wing span — 172 ft. The progress which has taken place over the decades separating these two aircraft is remarkable.

As many of you have probably heard, the B-2 became fully operational on April 1st of 1997. We're not sure if April Fool's Day was an appropriate day or not, given the known performance of the B-2 versus the government's proclivity to abandon military projects involving tailless aircraft (YB-49, A-12 "Dorito," etc.). At present, thirteen aircraft are deployed at Whiteman Air Force Base; a total of 21 will be sited there by the end of 1998.

Several years ago a large scale YB-49 was flown at the Slope Scale Fun-Fly in Richland, Washington. What an exciting prospect to have a B-2 "Spirit" in the same scale! If any readers of "On the 'Wing..." have completed and successfully flown a model of the B-2, regardless of size, we'd very much appreciate hearing from you!

	YB-49	B-2 “Spirit”
Span	172 ft.	172 ft.
Area	4,000 sq. ft.	5,140 sq. ft.
Engines	Eight J35-A-5 4,000 lbs. thrust each	Four GE F118-GE-100 19,000 lbs. thrust each
Weight, empty Weight, gross	88,100 lbs. 213,000 lbs.	153,700 336,500
Speed, max.	520 mph	high subsonic
Service ceiling	42,000 ft.	50,000 ft. with terrain following
Range	4,450 miles	6,000 miles without refueling
Payload	36,760 lbs. for 1,150 miles	more than 40,000 lbs.
Crew, min.	3, 5, or 7, depending on mission	2 or 3, depending on mission
Computers	none	more than 150

References:

Jones, Lloyd S. *U.S. Bombers; B1 - B70*. Fallbrook California: Aero Publishers, Inc., 1966.

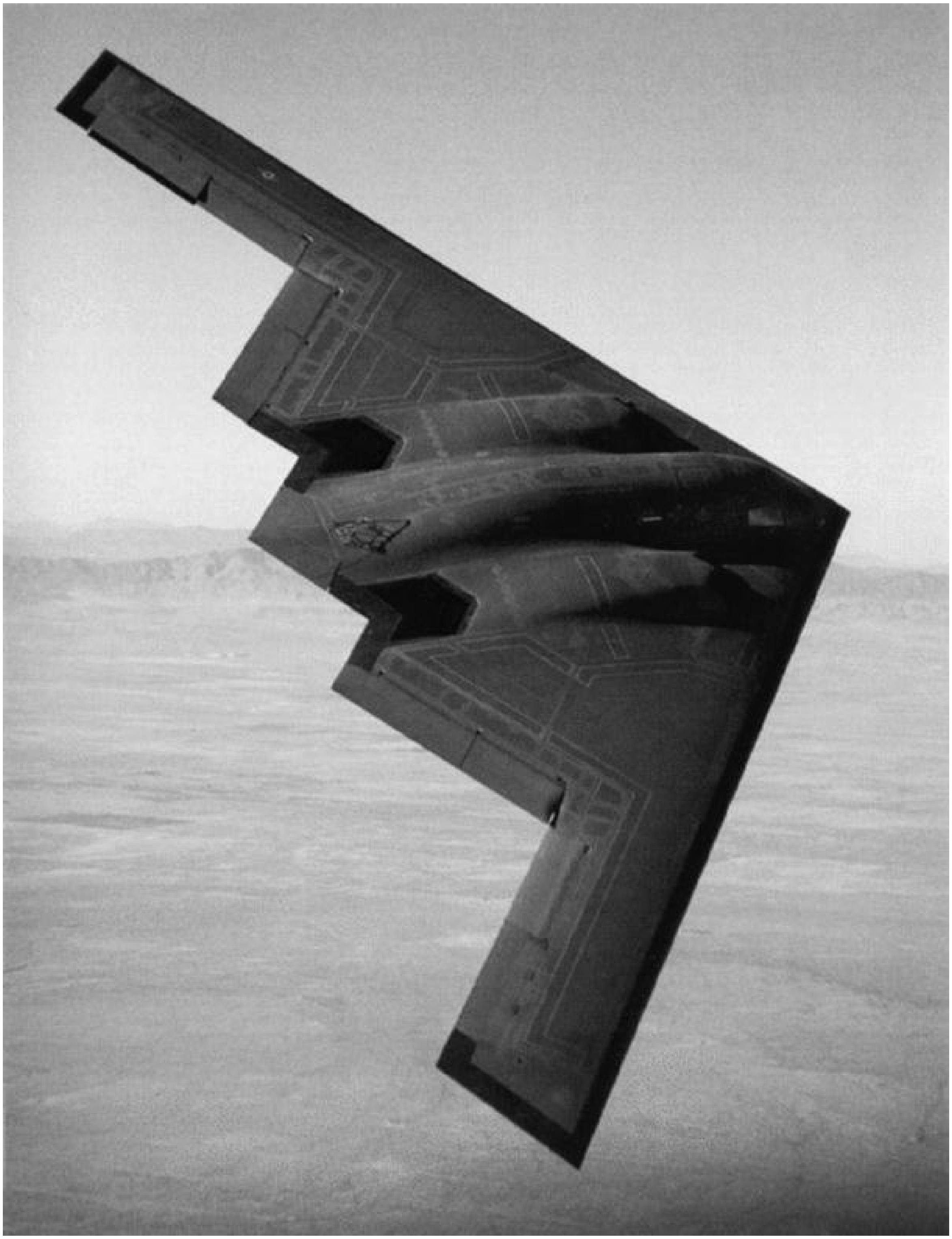
Northrop Grumman web site: <http://www.northgrum.com>

Nurflugel web site: <http://www.nurflugel.com>. (Information on subscribing to the Nurflugel e-mail list is on this site.)

United States Air Force. *USAF/B-2 Industrial Team*. United States Air Force, 1992.

Whiteman AFB web site: <http://www.whiteman.af.mil>

Wooldridge, E.T. *Winged Wonders; The Story of the Flying Wings*. Washington, D.C.: Smithsonian Institution Press, 1985.



Updates! to previous columns

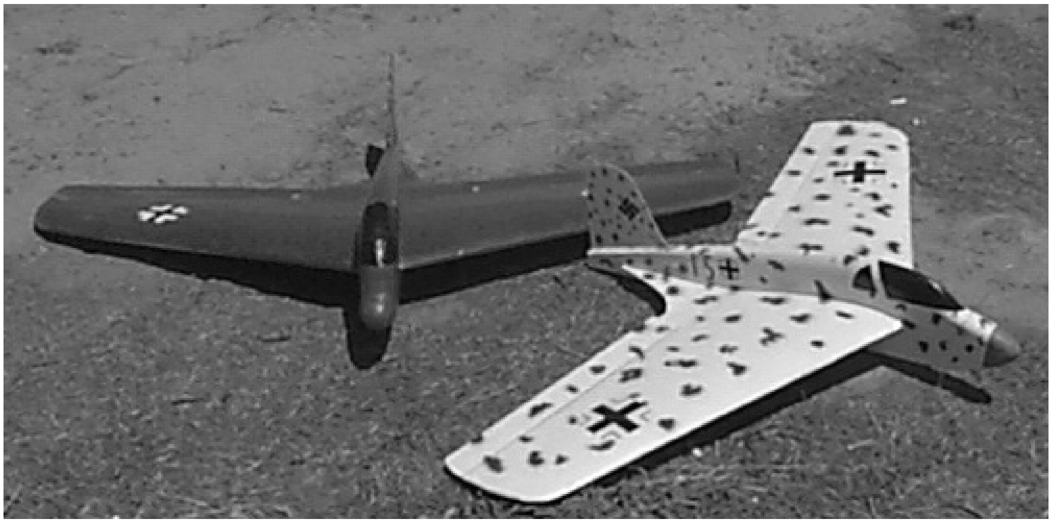
Komets! (July 1996)

When we wrote our column on the "Komet" series in July of 1996, we mentioned the Me 163A as a possibility for a thermalling model. Well, Dave Sanders' Dave's Aircraft Works (DAW) and Marc and Richard Webster's Silent Squadron R/C should both have EPP foam models of the Me 163 available by the time you read this column.

The semi-scale DAW Me 163 was designed by Wade Kloos of the Laguna Niguel Slope Soaring Guild and sports the MH45 airfoil. The fuselage has been "flattened" a bit (but it's not a profile model); the wing is single taper, like the Me 163B. Light lift performance on the combat slope is said to be fantastic, and yes, it will thermal over flat land!

Sensei John Roe was bungee and hand launching one of the prototypes at a contest in Pasadena on July 27th. For some neat photos of this new Komet, take a look at Sensei Roe's RC soaring web page at the following URL: <http://ourworld.compuserve.com/homepages/sensei_john_roe/ridethew.htm>. DAW can be reached by 'phone at (714) 248-2773, by e-mail at <104271.3352@compuserve.com> or by regular mail at 34455 Camino El Molino, Capistrano Beach CA 92624.

	Dave's Aircraft Works Model B/C	Silent Squadron R/C Model A
Span	49"	46"
Area	432, 3 ft^2	437, 3.035 ft^2
Weight	18-22	23-25
Loading	6-7.33 oz/ft^2	7.58-8.24 oz/ft^2
Misc.	semi-scale MH 45 airfoil	scale carbon spar system
Price	$59.99 plus shipping	$64.95 plus shipping



Two DAW Me 163 Komets ready for combat.

Silent Squadron R/C now makes a scale Me 163A. It, too, was demonstrated at the Pasadena two day event. The plane was being zip launched with a 5/8" x 25' bungee, and launch height exceeded that of the contest winches. The plane is capable of speeds in excess of 100 miles per hour off of the zip start, aided no doubt by its sturdy 1/4" carbon spar.

The Silent Squadron kit comes with the fuselage cut in profile and plan view, and needs about a half hour of sanding to shape properly. The wingspan and fuselage length and width are scale. This "Komet" will thermal, too! Contact Silent Squadron RC by 'phone at (805) 297-3948 or by mail at 22912 Frisca Dr., Valencia CA 91354.

Trick R/C's "Zagi LE" (January 1997)

The ZAGI-LE has to be one of the most successful RC glider designs in a very long time. The Zagi is a constant topic of discussion on the RC Soaring Exchange, the e-mail list run by Mike Lachowski with the facilities of *Model Airplane News*, and a large number of ZAGI kits have been sent overseas to both Europe and Japan. It seems to get rave reviews everywhere it goes!

Paul Clark, who flies off a river retaining wall in Japan, constructed one using every trick he could think of to keep the weight down. Guess where Paul and his son, taking a break from college, went as soon as they had the opportunity?

We've heard of people making double and triple size ZAGI slopers, and there's a small contingent who take their ZAGIs out for flat field flying using just the rubber tubing from a high start to get into the air — it's called zip launching. While this method can put some extreme loads on the airframe, the ZAGI seems to be up to it.

Trick R/C, Jerry Teisan, 938 Victoria Ave., Venice CA 90291. To order call (310) 301-1614. You can find also send e-mail to <Zod@zagi.com>, or find Trick R/C on the World Wide Web at <http://www.zagi.com>.

NASA/McDonnell Douglas X-36 "Backgrounder" (May 1997)

The X-36 flew for the first time on 17 May 1997. The flight lasted about five minutes, and the X-36 got to an altitude of around 4,900 feet. Reports stated the flight went very smoothly, with no surprises. In fact, its "flyability" was praised by those involved.

We also received an e-mail message from Al Bowers stating the canard surfaces do in fact move. They are used to control the airflow over the wing

The NASA/McDonnell Douglas X-36 remotely piloted aircraft lifts off on its first flight. The aircraft flew for five minutes and reached an altitude of 4,900 feet. The flight took place at NASA Dryden. NASA photo by Carla Thomas.

during landing. The picture included in our column in the May 1997 issue of *RCSD* does show the canards rotated to a very high angle of attack during taxi trials.

Dennis Weatherly's "JackWabbit" (July 1997)

In June we had the opportunity to meet Dennis Weatherly and watch his "JackWabbit" fly. What an exciting experience!

The "JackWabbit" has only a 30 inch wing span, and so Dennis keeps it relatively close by. The problem is that it is so darn fast! Dennis really put the "JackWabbit" through its paces, doing loops and rolls, Immelmans and high speed passes. The special 5x5 prop hauls that little devil around the sky as though it were on rails.

When we spoke with Dennis he talked seriously about furthering the development of the "JackWabbit" — making a more streamlined fuselage and perhaps trying a thinner section than the EH 2/10 used on the original. He was certainly enthusiastic about its potential in Speed 400 pylon racing. We'll keep *RCSD* readers informed of future "JackWabbit" developments.

Jim Keller's "Zephyrus" (August 1997)

Jim Keller's "Zephyrus" is still going strong. He's added ballast as the winds on his slope have become seasonally stronger, and his "Zephyrus" now weighs 22 ounces.

Jim had an interesting experience with his "Zephyrus" a while back. It went into a spin half way through a loop. This brought back our memories of some very strange gyrations performed by one of Alan Halleck's wings while flying on the Columbia River gorge.

Alan was flying his swept wing with a moveable CG. When the CG was forward, the glider had no problem at all completing loops. But when the CG was moved back, the 'wing would quickly roll upright at the top of a loop. It would also enter a spin, something it would not do when the CG was forward. The only way to recover from a spin was to quickly move the CG forward again and hope there was room to recover.

The behavior of Jim's "Zephyrus" exactly matches that of Alan's 'wing at the Columbia gorge that day. Such experiences point out the necessity of accurately placing the CG relative to the neutral point. While performance improves as the CG is moved back, there is a rear limit, and it's always forward of the NP.

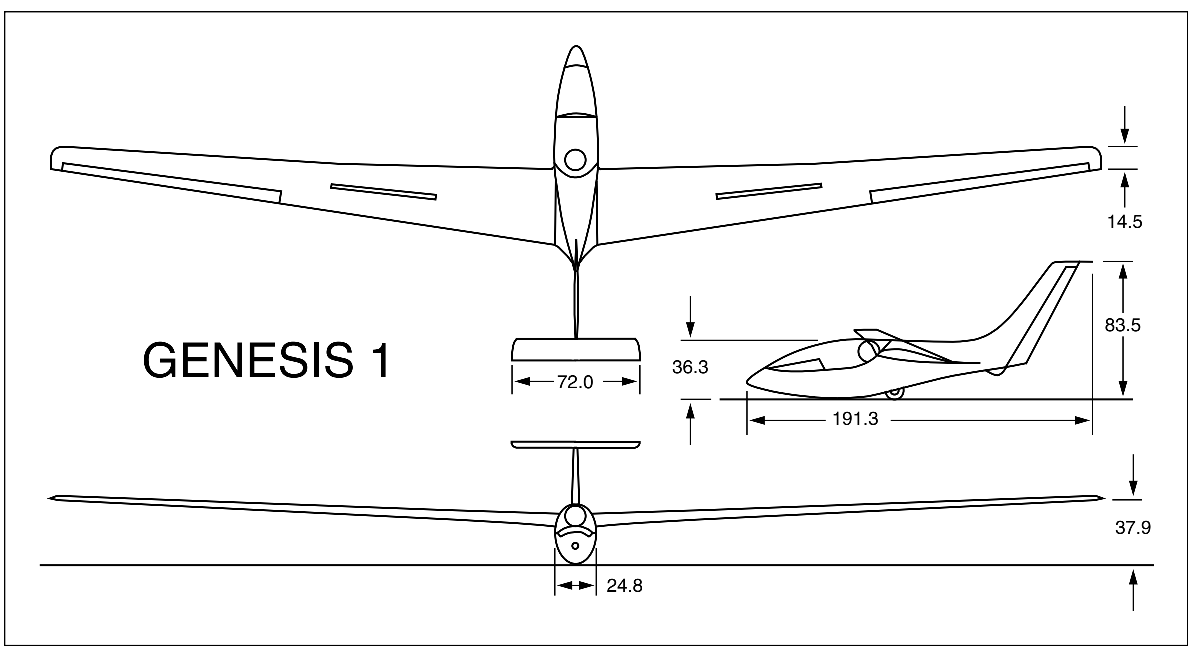
Group Genesis'
Genesis 1 and Genesis 2

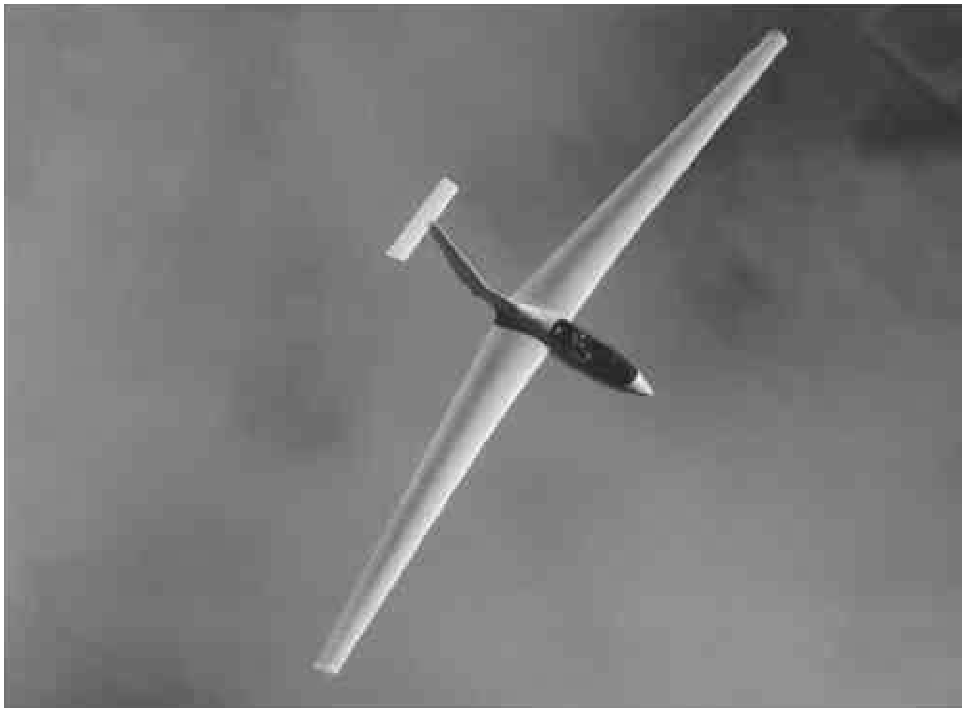
In 1988 we received a letter from Jim Marske, designer of the Pioneer II series of tailless sailplanes. The letter explained how John Roncz had come up with some excellent airfoils for aircraft using the Pioneer II planform. These new airfoils demonstrated laminar flow over a major portion of the upper surface and nearly the entire lower surface. This was exciting, as the laminar flow was in evidence over a wide angle of attack range.

A few years later, in 1994, we saw an advertizement for the Genesis 1 sailplane in the May issue of *Kitplanes* magazine. The included 3-view, although small, portrayed the Genesis 1 in an impressive manner. Contacting the factory netted us a very nice letter from Jerry Mercer, and promotional information sufficient to build a scale model.

The Genesis was designed to meet a goal - design the best Standard Class sailplane in the world - by achieving several objectives:

- take advantage of the efficiency of a tailless planform;
- produce a superior product at a lower price;
- achieve better performance than Klaus Holighaus's Discus while maintaining relatively docile handling characteristics.





An overhead view showing the gently forward swept wings

Engineer for the Genesis project is Jim Marske, of Pioneer and Monarch fame; the airfoil was designed by John Roncz, best known as the designer of the airfoils used on the 'round-the-world Voyager.

Genesis 1 was developed nearly entirely on computer. A complete description of the design process, including software used, was published in the September 12th 1994 issue of *Design News*.

The Genesis has forward swept wings, a short fuselage, and a "thresher" vertical tail. It is a tailless sailplane, despite what looks to be a horizontal stabilizer at the top of the vertical surface. That horizontal surface is a full flying trim tab, used only to set the angle of attack of the wing. Its position is as far aft of the CG as possible, thus providing a maximum lever arm, thus reducing required deflection angles. The wing sections, sweep, and wing twist have been designed to make the main wing entirely self-stabilizing.

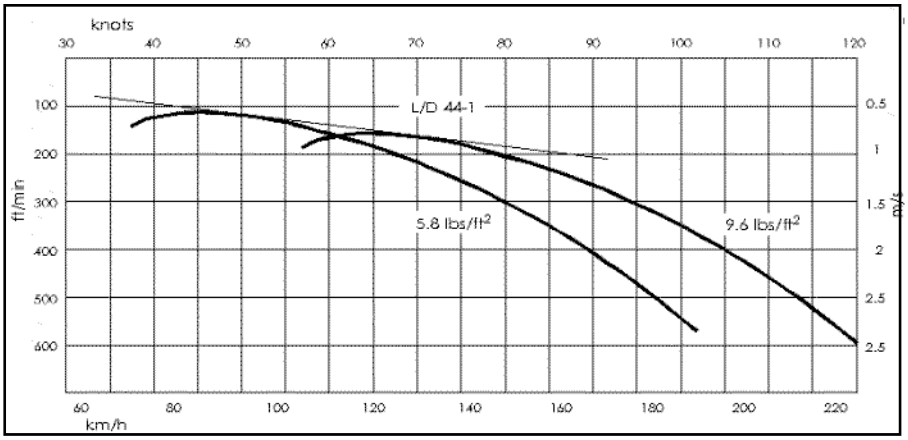
Maiden flight of the Genesis took place on November 15 1994. Optimization of the design came through several hundred hours of flight testing, over half of which were flown under competition conditions. The improved design was given the name Genesis 2, and includes the following improvements over the Genesis 1:

- Genesis 2 will be almost 150 pounds lighter, allowing a greater wing loading range;

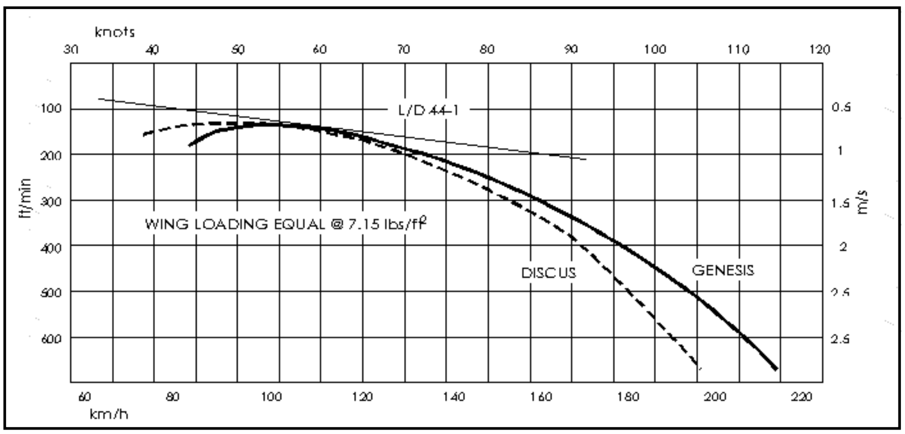
This photo shows the high aspect ratio "thresher" vertical stabilizer and sleek fuselage shape.

- aerodynamic twist was reduced by nearly two degrees, improving climb and high speed performance;
- the wing tip and outer wing airfoil sections have been refined to generate more lift while creating less drag;
- a retractable nose wheel has been added;
- fuselage contour lines and fairings have been smoothed and modified to reduce airflow separation;
- the leading edge radius and airfoil section on the vertical stabilizer have been modified also to reduce drag;

Genesis in flight over Marion Ohio



Genesis 2, 5.8 and 9.6 lbs./ft^2



Genesis 2 vs. Discus, 7.15 lbs./ft^2

- aileron control forces have been made lighter through better mechanical advantage, a changed aileron aspect ratio, and new aileron hinge points;
- a new canopy separation line gives better visibility.

The included polars show the performance of the Genesis 2 at wing loadings of 5.8 and 9.6 lbs./ft^2, and against the Discus at 7.15 lbs./ft^2.

The Genesis 2 is currently being manufactured by Sportine Aviacija, formerly LAK (Aircraft Factory of Lithuania). A completed Genesis 2 sailplane, certified in the Experimental/Racing category, is $44,900 (U.S.) FOB Lithuania.

Charlie Fox, of Davenport Iowa, built a 1/3 scale "proof of concept" model of the Genesis 1 for Group Genesis. The model is capable of very steeply banked turns and thermals easily. Gordy Stahl wrote about Charlie's model in the February 1995 issue of *RCSD*.

For more information contact:

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E-mail: groupgen@aol.com
WWW: http://www.groupgenesis.com

All photos included in this article are from the Group Genesis web site. For a movie of the Genesis in flight, download the following file: http://www.groupgenesis.com/glider.mov

Genesis 1 Specifications		
Structure	Composites: Hexcel fiberglass throughout, carbon fiber spar caps, and Kevlar layers around cockpit	
Airfoil	Roncz G-74S	
Wingspan	15 meters	49 ft. 2½ in.
Length	4.87 meters	15 ft. 11¼ in.
Height	2.13 meters	6 ft. 11-1/2 in.
Wing area	11.20 m^2	120.5 ft^2
Aspect ratio	20.2	
Empty weight	223 Kg.	490 lbs.
Payload	303 Kg	667 lbs.
Gross weight	525 Kg	1157 lbs.
Maximum wing loading	46.9 Kg/m^2	9.6 lbs./ft^2
Maximum L/D	43.2 @ 120.6 km/h*	43.2 @ 74.9 m.p.h.*
L/D @ 100 knts	29.5	
Minimum sink	0.58 m/s @ 83.47 km/h.*	1.9 fps @ 51.75 m.p.h.*
Stalling speed	68.6 km/h. *	42.6 m.p.h. *

* = estimated


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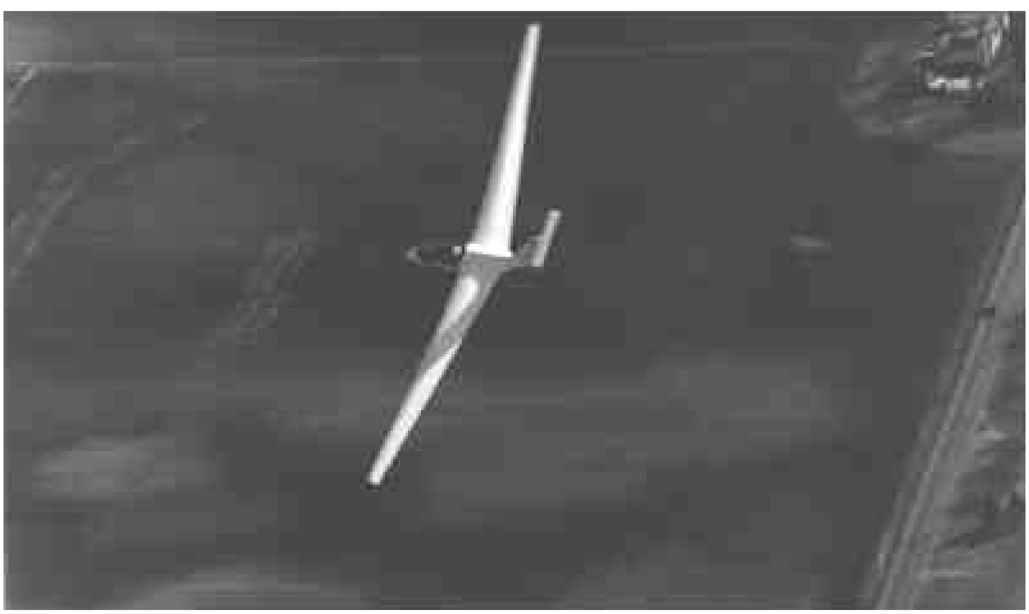


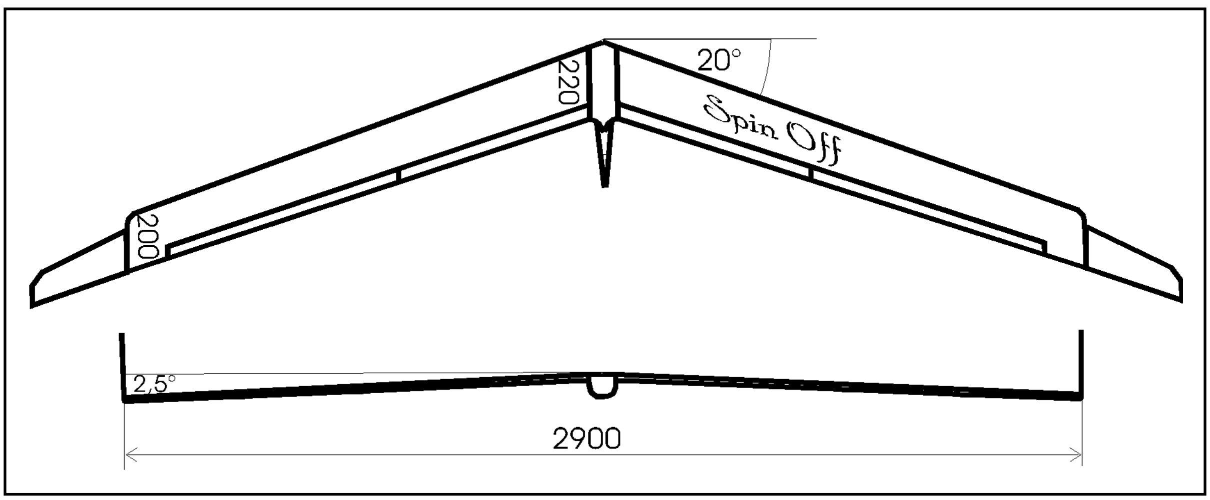
Christian Behrens & ChristianTollmien's "Spin Off"

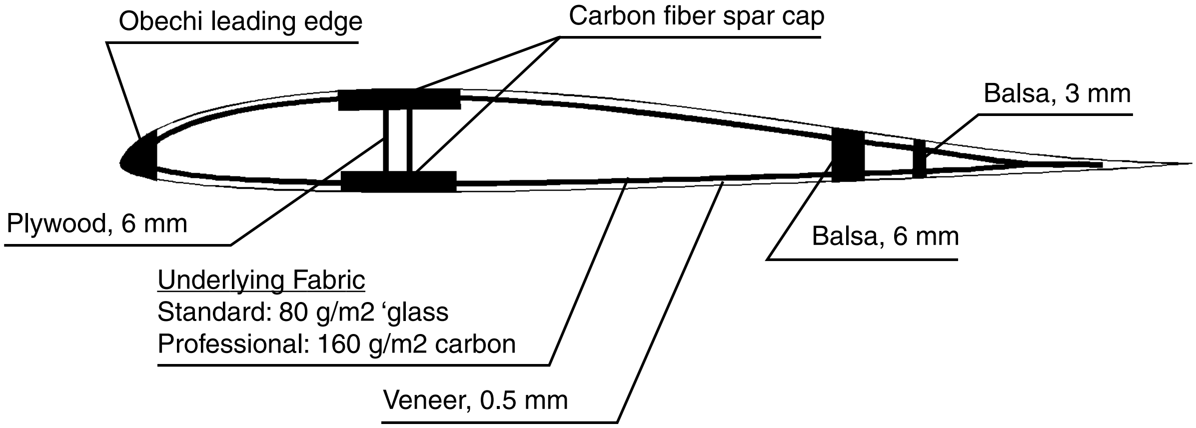
This month we take a look at another highly competitive tailless model from Germany, with thanks again to Andrew MacDonald of Australia for providing the information.

"Spin Off" is the creation of Christian Behrens and Christian Tollmien, and has so far gone through four iterations. The most successful version was the second, and it is the one described here. The number three version was the worst of the series, which just goes to show that subsequent modifications do not always yeild improvement!

Although "Spin Off" was inspired by Hans-Jürgen Unverferth's Joined series, comparing the Spin Off with Hans-Jürgen Unverferth's CO^7 yeilds some very interesting information. This is particularly enlightening as the CO^7 and the "Spin Off" are the best performing tailless saiplanes in Germany at this time. For those who think the sections used on tailless models cannot produce much lift, the two Christians say this model can break the winch line.

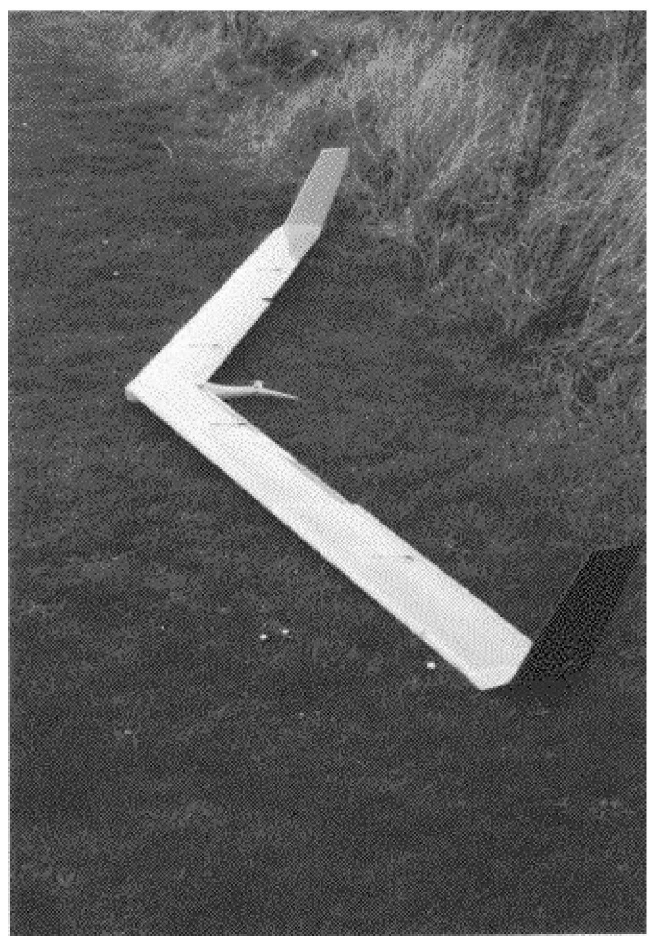
Behrens and Tollmien are very sure of the thermal potential of this model, and say they will have no problems with the extended thermal duration task coming for F3B. Christian Behrens admitted their lack of experience has prevented them from doing better in F3B as they haven't enough practice in tuning their models for different conditions, and lack of identical mold-built prototypes makes them cautious against trying radical techniques for





launching and otherwise improving contest performance. But he is pretty confident that if anyone turned up with a “Spin Off” against average pilots they have a good chance of placing well.

Both Christians are in the C-Kader F3B division this year and in the German National Championships for F3J. Christian Tollmien came in the top 26 out of over 130 entrants. He also said that the number of people flying tailless competitions has dwindled and he attributes this to the fact that no one can compete with them or Hans-Jürgen. If someone turns up at a tailless competiton with a new glider, and they suddenly find themselves at a 50 meter height disadvantage to a “Spin Off” or a 70 meter disadvantage to a CO[7], they tend to be discouraged. Christian and Christian fly with Hans-Jürgen, and while they help each other they are fairly competitive as well.



"Spin Off" is available from Christian Berhens. He is selling two different versions. The general sport model (Standard) uses 'glass, while carbon is used for the competition model (Professional). Prices are around 600 DM for the 'glass version, 1000 DM for the carbon version. Shipping is not included in these prices.

"Spin Off" dimensions	
Wing span	2.9 meters
Wing area	60.9 dm^2
Aspect ratio	13.9
Weight, Standard Professional	1900 g 2100 - 3000 g
Wing loading, Standard Professional	31 g/dm^2 33 - 50 g/dm^2
Design C_L (neutral trim)	0.3
Profile	S 5010
Dihedral	-2.5 degrees

Modellflugvertrieb
Christian Behrens
Geysostrasse 13
38106 Braunschweig
Germany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