# Radio Controlled Soaring Digest

May 2013 Vol. 30, No. 5

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**May 2013**

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**Front cover**: Joe Nave's Maxa 3.9 at the beach in Hawaii getting some rest… ;). Photo by Joe Nave.
Apple + Pro HDR iPhone, ISO 64, 1/4600 sec., f2.4



**Back cover:** Alejandro Arroyo sent in this photo under the title "F5J - Da Costa (Mar del Plata - Argentina)." What a relaxed atmosphere!
Sony DSC-W35, ISO 100, 1/320 sec., f8

# R/C Soaring Digest

## May 2013

### Volume 30 Number 5

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Published by B2Streamlines <http://www.b2streamlines.com>
P.O. Box 975, Olalla WA 98359



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*RC Soaring Digest* is published using Adobe InDesign CS6


# In the Air

There are several items deserving of your attention this month.

First, thanks to Morten Enevoldsen for letting us know how well Google Advanced Search works in finding materials previously published in *RC Soaring Digest*. This search engine indexes the <u>text</u> contents of PDFs. It does not index images, so it will not search the *RCSD* issues prior to April 2002 — the search engine on the *RCSD* web site works well for that. But Google Advanced Search does work marvelously well when you're looking for article titles or specific article subjects from April 2002 through the current issue. There's more information about using Google Advanced Search on page 4.

Helmut Schenk's article, "The determination of the longitudinal moment for the flying wing model," has been in our library since the mid-1990s. Originally in German, we owe immense thanks to Marc de Piolenc of the Philippines for the translation to English. In the interests of accuracy, various formulas and illustrations have been scanned from the original document and inserted directly. Anyone finding a typographical or other error is encouraged to forward appropriate revisions to us for correction.

"NASA Researchers Work to Turn Blue Skies Green" has been included in this issue because of three areas of research - (1) Active Flow Control Enhanced Vertical Tail Flight Experiment, (2) Damage Arresting Composite Demonstration, and (3) Adaptive Compliant Trailing Edge Flight Experiment. While aimed at full size commercial aircraft, the methodology and results of these experiments may hold benefits for RC soaring enthusiasts.

Time to build another sailplane!

B²

# SEARCHING / *RCSD* ARCHIVES

A searchable index has been available for a number of years through links on the *RCSD* web site. The index is provided as both a web page <http://ciurpita.tripod.com/rcsd/rcsd_index.html> and as a self-contained interactive search page <http://ciurpita.tripod.com/rcsd/rcsd.html>.

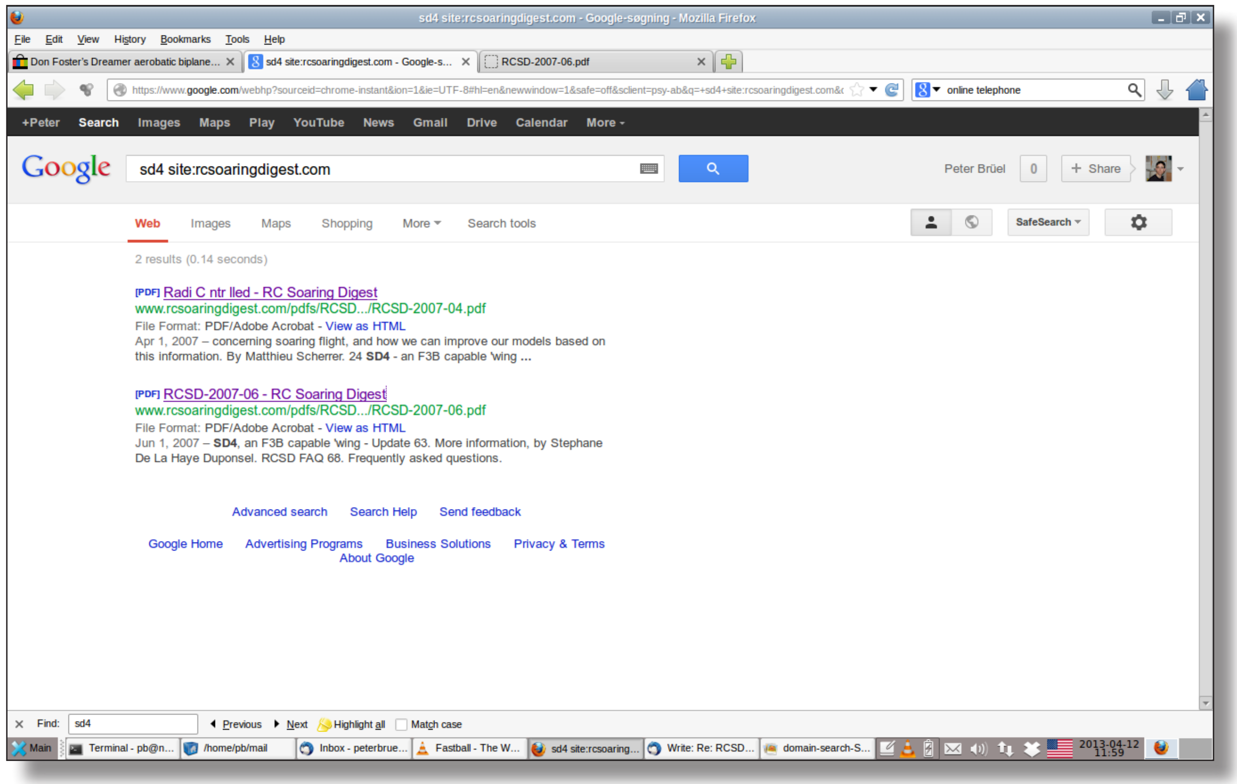
This index, created by Lee Murray, covers all *RCSD* issues only through April of 2005. The interactive search page was created by Greg Ciurpita and has been a very popular method of finding materials published through the years.

We have recently received a number of inquiries regarding the possibility of updating this index through the current issue, but updating the index within the current format would be a time-consuming manual process.

Thanks to a suggestion by Morten Enevoldsen, Denmark, we've been made aware of a convenient and viable alternative, Google Advanced Search <http://www.google.com/advanced_search?hl=en>, which now allows users to search PDFs within specific web domains!

Simply go to the Google Advanced Search page <http://www.google.com/advanced_search?hl=en> and fill out the upper part of the form using the parameters you wish, then go down the page and set the "site or domain" option to "rcsoaringdigest.com."

From there it's only a matter of clicking <Advanced Search> and watching the results appear as illustrated by the screen grab below.




*Peter Bruel did a search for "SD4," a tailless F3J model by Stephane De La Haye Duponsel which he knew appeared in the April 2007 issue and is now archived at rcsoaringdigest.com. The advanced search found Stephane's SD4 follow-up article published in the June 2007 issue.*

# Cumberland Maryland

# Spring Soar-For-Fun 2013

Pete Carr WW3O, wb3bqo@yahoo.com

Photos by Pete Carr and Steve Pasierb

*This is the author with his 12 foot span Thermal Queen 3-channel sailplane. The transmitter is a very old Proline operating on 53.3 MHz in the 6-meter Amateur radio band. The ship was constructed from a Skybench Aerotech short kit.*

The weekend prior to Easter was the date for the 4th annual Soar-For-Fun on Old Knobbly Hill south of Cumberland Maryland. Jim Dolly had purchased the hill several years ago and veterans of the slope will appreciate the enormous amount of work he's done to the site. For example, the road going up the hill is significantly improved to the point where even small cars can make the climb.

As you may know, it's been one heck of a long winter. I say that because I went up to the building to pay the "landing fee" for the day and walked in on a lively conversation about doing grievous bodily harm to Punxsutawney Phil, the weather forecasting ground hog. The temperature that morning was a balmy 28 degrees and there was snow in the woods. What's up with that!

The sun was out and the wind was about 5 MPH from the west so everyone got busy assembling sailplanes. There were also several glider tugs which took turns with the tow duties throughout the day.

I'd brought a collection of old Ace MicroPro and Proline radios to fly and immediately regretted that. The aluminum cases really sucked the heat out of my

*Title page: The tow tug pulls another ship into the cold, crisp air. The grass was so short that even sailplanes with very small belly wheels had no trouble and rolled along on takeoff. Photo by Pete Carr* hands and gloves were no help. We set a winch out for those people who don't aerotow and there were quite a number of planes using the line. One Olympic II sailplane made its maiden flight off the winch and flew as beautifully and it looked.

There was a Northrop Primary glider on the field that was towed to altitude by the Super Decathlon tow tug. Jim Dolly was flying the tug and climbed out with the glider right behind. The tow speed was easily three times the normal flight speed of the ship so I could easily imagine the amazingly scale pilot with a serious laundry problem on landing.



*Upper right: This tow tug had interesting flap hinges. They were very heavy duty and the builder mentioned being able to drop flaps, then dive straight down to set up a landing for the next tow. The lettering on the wing is [www.rcaerotowing.com](http://www.rcaerotowing.com). That's a the web site devoted to that segment of the sport and Steve Pasierb, the web host, was on the field to discuss the activity with prospective tow pilots. Photo by Pete Carr*

*Right: Dr. Jim Dolly both owns the Highpoint Aviation flying field (actually the top of an entire mountain!) and this trusty Pilatus Porter tow plane. Powered with a DA-85 motor, Jim made a range of improvements and modifications that make this great tow platform even better. Photo by Steve Pasierb*


Don Chamberlain of Connecticut hauls his 1:3 scale Valenta Fox over to the tow queue. This is a robust aerobatic model that could actually benefit from the addition of ballast in some conditions. As is, it performs well on the slope and can also thermal in reasonable lift. Photo by Steve Pasierb


The front office of Steve Pasierb's stunning EMS Duo Discus. This 5.3 meter span sailplane has obechi wood sheeted over foam wings that were then glassed and painted with a custom harlequin design. Two Axel's Scale Pilots do duty at the controls inside a highly-detailed cockpit. Photo by Steve Pasierb

*A good view of the High Ridge Soaring / Troy Built Models 158” span ARF ASK-21 on tow. Look closely and the missing front wheel is visible, it broke on a hard landing and indicates that future owners should beef-up the light ply in this area of an otherwise nice performing sailplane and the subject of a build/fly review to appear shortly on RCAeroTowing.com. Photo by Steve Pasierb*

As you look through the pictures of the event it's easy to overlook the incredible amount of detail on the pilot figures and cockpits. I was particularly impressed by the watch on one pilots' wrist and the stitching on the parachute straps on occupants of a two-place sailplane. One small pilot also had a white beard and a very self satisfied grin on his face!

While I very much enjoy seeing the wonderful workmanship of these details I really like looking inside the ships at the radio installation and linkage hookups. It was noteworthy that most all the servos in use were Hitecs and a great many were still the analog type. The tow tugs had split elevators with the servos in the rear of the fuselage and also servos for rudder and separate tail wheel. Needless to say, that number of servos puts an enormous load on the battery.

*This scale sailplane uses a plywood mounting plate in the radio room. At left is the rudder servo with a short push rod to a bell crank. Pull-pull cables run from the bell crank to the rudder. The bell crank looks very much like those from control line aircraft. At right is a LED bar graph expanded scale volt meter that is visible with the canopy closed. Photo by Pete Carr*


*This Let Models ASH-26 spans 6 meters and was both a fantastic performer and quite aerobatic during Friday's heavy slope lift. It sports a huge solid carbon wing rod.  Owned by Steve Pasierb of Connecticut, custom paint and graphics by Alvaro Corzo. Photo by Steve Pasierb*

*The H Models Arcus departs beautiful Highpoint Aviation field on another tow over the valley below.  This plane certainly performed in slope conditions, but also showed a keen capability to maximize thermal lift. Photo by Steve Pasierb*

*I was very impressed at the detail of the canopy on this sailplane. Then I met the builder and realized that the pilot figure inside was a self portrait of him. The beard was accurate and he had the same smile when he talked about flying the ship.*
*Photo by Pete Carr*

*A proper pilot is a perfect touch to a vintage scale model. This handsome devil is from Axel's Scale Pilots and occupies the cockpit of Steve Pasierb's huge 6.3 meter span PWS-101 model sourced from Old Gliders of Poland. He both looks right for the model, and happy to be at Soar-For-Fun!*
*Photo by Steve Pasierb*

One of the ships had an LED bar graph expanded scale volt meter installed that could be viewed with the canopy closed up for flight. This high degree of workmanship was proven by the fact that none of the aircraft suffered any damage the entire day.

About noon the wind came around directly into the hill and freshened to about 8 knots. The lift was excellent well out over the valley but spotty in closer to the field. It was wonderful to see a 6 meter glass sailplane performing slow axial rolls and half pipes under the occasional puffy cloud. It would make high speed passes down the length of the landing strip at 50 feet then turn out over the valley, regain height and do it all again.

I'd brought a Thermal Queen to fly that was from a Skybench Aerotech short kit. I'd built it several winters ago and it had about a dozen flights on it. The radio is a reworked Proline Competition Six which is of the time period of the original TQ design. This is one of Carl Lorbers designs as is the Gaggler which I had also brought along. I put the Queen up the winch line and was standing there enjoying it as it got small in a hurry. Soon several guys, including Meyer Guttman, came over and we chatted. Now, I 'd spent several months putting the 12 foot span ship together and engineering the radio install. I'd taken extra care with the Monocote color scheme and all the little details that make up a big sailplane. However, that was low priority to my fellow fliers. All they talked about was Proline transmitters and stories about memorable planes and flights of so long ago. There was even some discussion about reed radios and how much fun it would be to fly one these days with the reliable batteries and better servos. One gentleman, who shall remain nameless, indicated that he's flown reeds for several years and found the radio very reliable. With an optimistic outlook like that and little recall of actual events he should run for political office.

*That's not Grizzly Adams, that's Tom Pack sporting his other winter project, a thick beard! You can see he's grinning ear to ear after another successful flight. Photo by Steve Pasierb*


*This museum-quality Baby Bowlus was originally hand-crafted a very long time ago by the late Joe Radoci of Baltimore. The plane was mostly displayed at hobby shows and then stored away for well over a decade. Erich Schlitzkus acquired it from the Radoci estate and put it back into service with great success. Photo by Steve Pasierb*


*Above: A striking Schneider Grunau Baby that was completely remade from a not too impressive Asian ARF with fresh covering and custom paint. A vintage Axel pilot is the cherry on top. It is owned and flown by Charlie Reeves of Delaware. Photo by Steve Pasierb*

*Right: The pilot figure of this ship has a nice silk scarf and very detailed goggles which would be needed in this ship with no windshield. The fuselage is wedge shaped on the bottom so the bungy cord secures it in a cradle for shipping and assembly. Photo by Pete Carr*


This A4 Skyhawk is noteworthy because it has appears in RC Soaring Digest. The scale documentation on the ground in front of the ship shows the RCSD picture and writeup. There was not a blemish anywhere on this sloper. The finish and markings were terrific. Photo by Pete Carr

This German Me-163 foamy was towed up and flew wonderfully. I was particularly impressed that it had no problem with wake turbulence from the tow tug. Photo by Pete Carr


The Valenta Fox passes by on tow during Saturday's gorgeous warm and sunny conditions.  Absent rear cockpit detail, it's possible to see the strong sun rays lighting up the interior of the fuselage. This is the beauty of scale soaring! Photo by Steve Pasierb

Out of the five days scheduled for the event only Saturday was suitable for flight operations. The combination of cold temperatures and a snow storm coming up from the south made this essentially a single day event. For those pilots who drove long distances and pull a trailer full of planes it's a shame the weather didn't cooperate a bit more. Still the year is young and there's always the fall Soar-For-Fun at the hill to look forward to.

My thanks go out to the ladies and gentlemen who worked in the building making coffee and lunch and listened so politely to the tall tales of the pilots as they chatted.

I also want to thank Jim Dolly for inviting us to enjoy his slice of Heaven on that wonderful Spring day.


*The H Models Arcus by Radim Horky strikes a commanding presence on the flight line and in the air.  Spanning 6.6 meters, this is the carbon version owned by Len Buffinton of Connecticut. It appears capable of handling any flight maneuver and stress thrown its way and makes impressive low inverted passes to the crowd's delight. Photo by Steve Pasierb*


*A Ka-3 with a color scheme and numbering matching that of its full size counterpart. It flew beautifully. Owner unknown, unfortunately.*


*Tom Pack of Virginia built this beautiful 1:4 scale TG-2 from plans. Completely docile on tow and landing, it's design is a natural for thermal flight. Another example of great scale detailing representative of the planes seen at Cumberland. Photo by Steve Pasierb*

# An effective means of exiting a glider-eating thermal

Chris Evans, <http://www.scipie.com>

Today I treated my club mates to a demonstration on how to exit a glider-eating thermal. Here's the basics...

When you realize your glider is not coming down, deploy the spoilers.

If you find you're still going up regardless, roll inverted and you should start to descend.

For good measure pay no attention to your airspeed and then when the wing rips off (and this part is important), begin yelling "heads-up, heads-up, heads-up!"

The sailplane will then proceed to exit the thermal in a nose down spiraling-out- of-control sorta fashion.

Continue to yell "heads-up" until impact at which point a loud crunching/crashing sound will take over and pretty much ensure everyone at the field is well aware you're down from the thermal.

Works like a charm.

# Determination of the longitudinal moment for the flying wing model

by Helmut Schenk, translated to English by Marc de Piolenc

The equilibrium of the longitudinal moments

At first sight the flying wing model seems to be a more simple configuration compared to the model with tail. Because there is no horizontal tail surface, only the total lift A (from Auftrieb) and the zero moment $M_0$ contribute to the longitudinal moment about the center of gravity SP (from Schwerpunkt), see Picture 1.

It holds

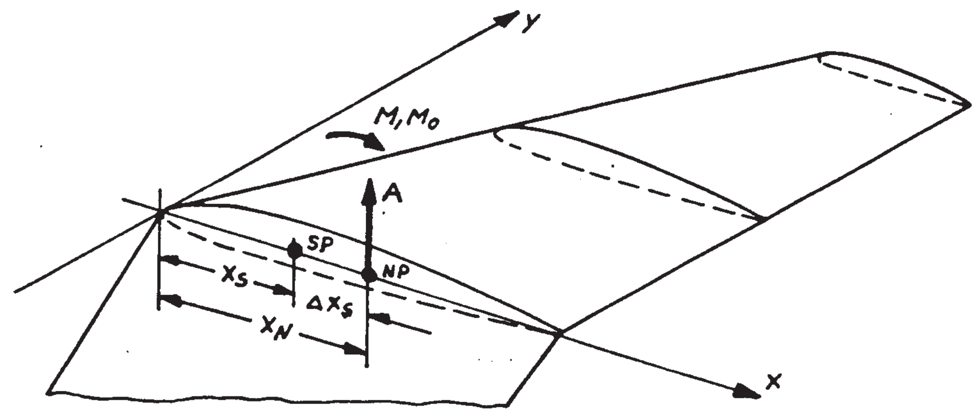
$$M = M_0 - \Delta x_s \cdot A \qquad \text{<eqn. 1>}$$

$M_0$ is the so called zero moment of the wing and has a constant value, independent from the angle of attack. The name zero moment comes from the fact, that it is still existent (and with unchanged value), if the lift becomes zero. It is well known that $M_0$ can be written or calculated as

$$M_0 = c_{m_0} \cdot q \cdot F \cdot l_\mu \qquad \text{<eqn. 2>}$$

Here q is the pressure head, F (from Flaeche) is the wing area, $l\mu$ is the so called reference chord length, and $c_{mo}$ is the coefficient of the zero moment.

The latter must not be mixed up with the coefficient of the zero moment of an airfoil (for example for the well known Eppler airfoils), though it is basically the same thing. The airfoil coefficient is an airfoil specific value which is only valid for a given wing section, while the coefficient in eqn. 2 depicts a coefficient of the whole wing, which is still to determine.




Picture 1

The lift A can be written as

$$A = \overline{c_a} \cdot q \cdot F \qquad \text{<eqn. 3>}$$

The overline at $c_a$ means, that it is the resulting $c_a$ of the whole wing, i.e. the mean value from the lift distribution. As we know the resulting lift force can be imagined as working at the neutral point NP of the wing.

In eqn. 1 $\Delta X_S$ is the distance from the center of gravity SP to the neutral point. If we insert eqn. 2 and eqn. 3 into eqn. 1, we get for the moment

$$M = c_{m_0} \cdot q \cdot F \cdot l_\mu - \bar{c_a} \cdot q \cdot F \cdot \Delta X_S \qquad \text{<eqn. 4>}$$

or, after division by $q \cdot F \cdot l\mu$ the nondimensional quantity

$$c_m = c_{m_0} - \bar{c_a} \cdot \frac{\Delta X_S}{l_\mu} \qquad \text{<eqn. 5>}$$

with $c_m = M / (q \cdot F \cdot l\mu)$ being the moment coefficient of the wing.

In steady flight the moment or its coefficient must be zero, if not the model would turn around its roll axis because of the moment. $C_m$ must be zero, or

$$c_{m_0} - \bar{c_a} \cdot \frac{\Delta X_S}{l_\mu} = 0 \qquad \text{<eqn. 6>}$$

This is one of the most important formulae for the flying wing model, because it describes the equilibrium of moments without which a steady flight is impossible.

In eqn. 6 you see the expression $\Delta X_S / l\mu$. It depicts the relative location of the C.G. (Schwerpunkt) of the model, or more exactly the distance from C.G. to the neutral point divided by $l\mu$.

This value is of great importance for the longitudinal stability of the model (we will not go deeper into this). It is often called the measure of stability or STM (from Stabilitaetsmass).

The measure of stability must always have a positive value, that means the C.G. must always be in front of the neutral point, in the other case the model would not be longitudinal stable. Next to that the value of the measure of stability must be within narrow limits.

For normal tailed aircraft models the STM is between 0.07 and 0.15, depending on the design. For flying wing models the STM is between 0.03 and 0.12. It has smaller values than for tailed models. The value 0.03 is for flying planks or something like that, while 0.12 is for models with 20 to 30 degrees of sweep.

Using the STM we can write eqn. 5 and 6 as

$$c_m = c_{m_0} - \bar{c_a} \cdot STM \qquad \text{<eqn. 7>}$$

or, for the moment equilibrium

$$c_{m_0} - \bar{c_a} \cdot STM = 0 \qquad \text{<eqn. 8>}$$

From eqn. 8 we see: Because $c_a$-overline and STM are positive, also $c_{m0}$ must be positive, for eqn. 8 to be fulfilled.

If the moment is shown in a diagram dependant on $c_a$-overline, so we yield a straight line, see Picture 2a (next page).

Starting with $c_{m0}$ at $c_a$-overline = 0 the moment slopes down with the inclination STM until the $c_a$-overline axis is crossed. Here is $c_{m0}$ as in eqn. 8. The model is flying with the $c_a$-overline associated to this intersection point.

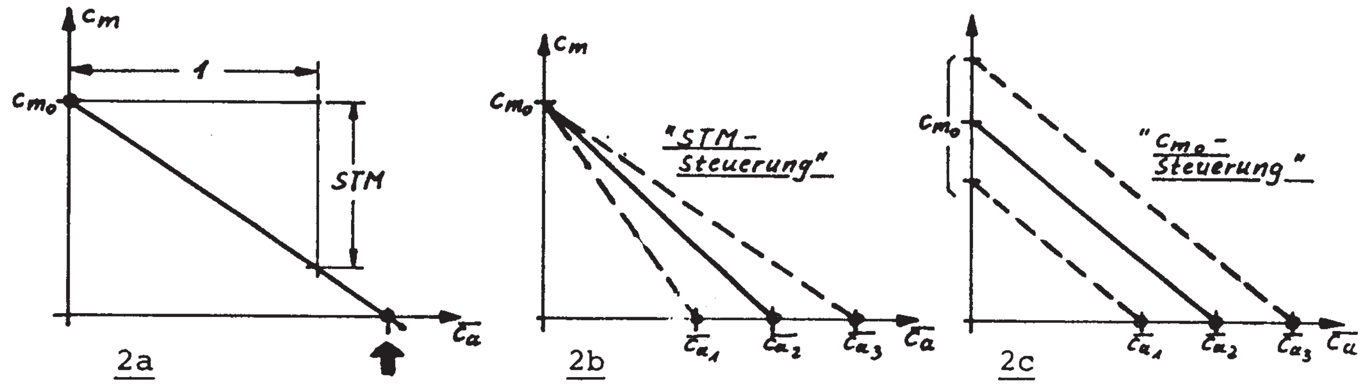
Basics of longitudinal control

At this point we can think about which possibilities we have for the longitudinal control.

It is well known that every steady flight path of the model is connected to a certain $c_a$-overline. You can imagine that a value of $c_a$-overline is chosen to achieve a desired flight path.

If we alter the $c_a$-overline in eqn. 8 to a desired value, also $c_{m0}$ or STM must be altered too, in order to the equation remains fulfilled.

The hang glider pilots, who control their aircraft by movement of the C.G., use the method “control by modification of STM.” This is actually not very favorable, because together with the longitudinal control also the stability relations are modified. But, as we know, practically this works quite well.




Picture 2

In Picture 2b you find depicted the control by modification of STM. Starting with the same $c_{m0}$ there are straight lines with different gradients resulting in different $c_a$-overline as intersection points with the $c_a$-overline axis.

In a model flying wing and in a man carrying flying wing also the C.G. is usually not variable during flight. That means in order to control the flight path the only possibility is to change $c_{m0}$. This happens by deflecting elevators and/or flaps. This method is shown in Picture 2c. The gradient of the straight lines ( = STM) stays unchanged, but the straight line is shifted by the modified $c_{m0}$. This also yields different intersection points with the $c_a$-overline axis with different flight paths.

Now we have seen that the zero moment or its coefficient $c_{m0}$ has a fundamental influence to the models characteristics, we have to deal with it more thoroughly.

<u>The components of the zero moments coefficient</u>

For a swept flying wing the zero moment consists of two components:

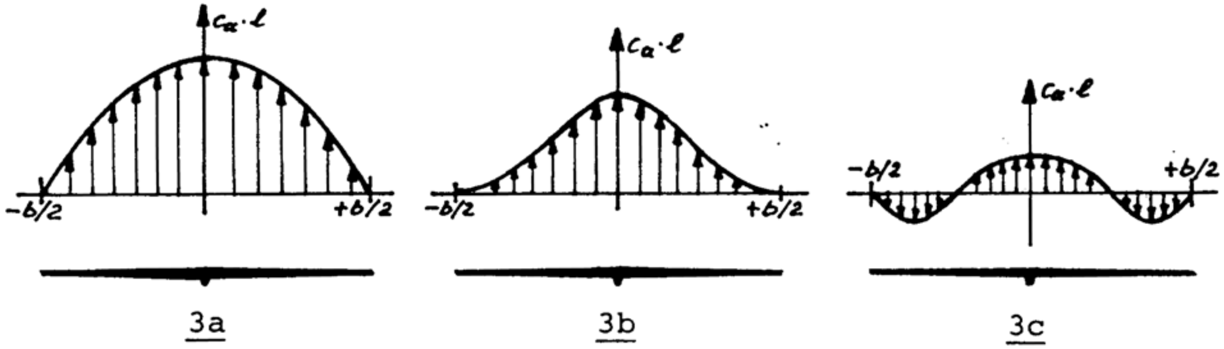
1. The zero moment of the airfoil; $c_{m0p}$

Each wing airfoil possesses a given zero moment coefficient which is dependent on the airfoils shape. It is determined theoretically or in wind tunnel experiments and is published together with the other airfoil data. The value of this coefficient can be negative, zero or positive.

Airfoils used for model aircraft usually have a nose heavy zero moment, using the normal sign rules (tail heavy = positive) that means a negative value. The so called “reflexed” airfoils have a positive value, symmetrical airfoils have a value of zero (this is somewhat simply said, but meets the heart of the thing).

All the wing sections of a flying wing with their in general different coefficients give, when added up, the first component of the total zero moment. During adding up one has to take care that for the moment of a wing section is responsible not only the respective coefficient, but the respective chord length as well. That is why the product $l \cdot c_{mp}$ is to add up, and from this the resulting mean $c_{m0p}$ is determined.

It would be wrong to simply use the mean value of the coefficients of the wing root airfoil and the wing tip airfoil.




Picture 3

For instance, when using a tapered wing more “moment is added up” at the root region than at the tip region.

The simple mean value is OK only in the special case of a rectangular wing. The exact formula for the tapered wing will be given later.

To characterize it, the component of the total zero moment coefficient that results from the airfoil will be given the index p (from Profil): $c_{m0p}$.

It depends only from the used airfoils and from the wing plan form - twist and sweep don’t matter.

2. The zero moment of the twist; $c_{m0s}$ (s from Schraenkung)

The origin of this second component is a little more difficult to understand than the first component.

It is characteristic for the swept and twisted flying wing; it arises only if sweep and twist are working together.

To understand this, we make a virtual experiment; imagine a (negative) twisted wing in the air flow. Its lift distribution at a large angle of attack will look about like Picture 3a.

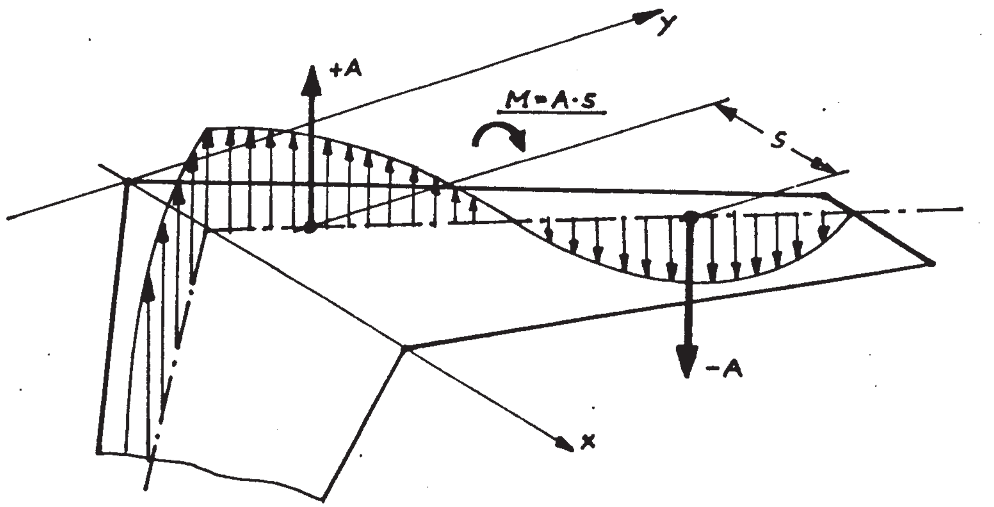
If we reduce the angle of attack, sometimes we get into a region of angles of attack where the wing tips have no more lift, but the wing root still has lift, see Picture 3b.

If we go on reducing the angle of attack, the wing tips produce down force, while the wing root still has small lift. At a special angle of attack, the so called zero angle of attack of the wing, the up force at the wing root is equal to the down force at the wing tips, the resulting mean lift of the wing is zero, see Picture 3c.

But now look at Picture 4 (next page).

If the wing is tapered, the wing parts with down force are in the back of the model, but the wing parts with up force are in the front. This means: Though the resulting lift is zero, a tail heavy positive moment exists originating from the distance between up force and down force. This moment is the second component of the total zero moment.

If the twist is measured between the angles of zero lift of the wing root airfoil and the wing tip airfoil, the airfoils themselves don’t matter, the component of the moment is than independent of the airfoils.




Picture 4

It is dependendt on sweep, twist, and to a small extent on the wing planform.

To characterize it, the coefficient of the zero moment of the twist will be given the index s (s from Schraenkung): $c_{m0s}$.

3. The sum of the two components

The total zero moment coefficient of a swept flying wing is therefore

$$c_{m0} = c_{m0p} + c_{m0s}$$ <eqn. 9>

For the first part the chosen airfoil is responsible, for the second part the chosen sweep and twist.

The first part can be positive, zero or negative - dependent on the airfoil. The second part is always positive, if we assume negative twist (turning upwards) and backward sweep.

As we know from eqn. 7, $c_{rn0}$ must be positive. The part $c_{rn0s}$ yields in any case the desired contribution to the total zero moment.

Under certain circumstances we can afford to have a negative first part, $c_{m0p}$; for instance caused by “normal” airfoils in the wing root region. Nevertheless the sum of both parts can be positive. This is an advantage of the twisted swept wing that can’t be underestimated.

If however we use a non-swept wing, i.e. a flying plank, the part $c_{m0s}$ is zero from the beginning. It only remains to use airfoils which have a positive $c_{rn0p}$, that are reflexed airfoils.

The non-swept wing has a considerable drawback: If we deflect the elevator in order to increase $c_a$-overline, the control surface has to go upwards. Doing so the $c_{m0p}$ is increased, but at the same time the airfoil is de-curved and thus the $c_{amax}$-overline, that had not been very large anyway, is decreased. Furthermore, when deflecting the control surface the model can stall for a short time because of the loss of camber.

To take remedial measures, if the control would not be caused by a control surface at the trailing edge, but by a small canard wing arranged in front of the wing. Doing so we get the so called short coupled canard. This aircraft type has again its own problems, so that here is a wide area for experimenting model builders.

Another drawback of the non swept flying wing is the small allowable region for the C.G. Because we only have $c_{m0p}$ to compensate for C.G. shifts, only small deviations from the ideal C.G. are allowed, if you don't want to have a loss in the usable $c_a$-overline range. With model aircraft, the C.G. is usually fixed and this drawback doesn't exist. Despite these drawbacks, successful flying plank designs are known, both man carrying and model aircraft. Altogether, the light swept wing seems to be more advantageous, it simply offers more possibilities for manipulating the different influence factors.

That is why here basically the swept twisted flying wing is treated. The special case of the flying plank is of course included if you make the sweep to zero.

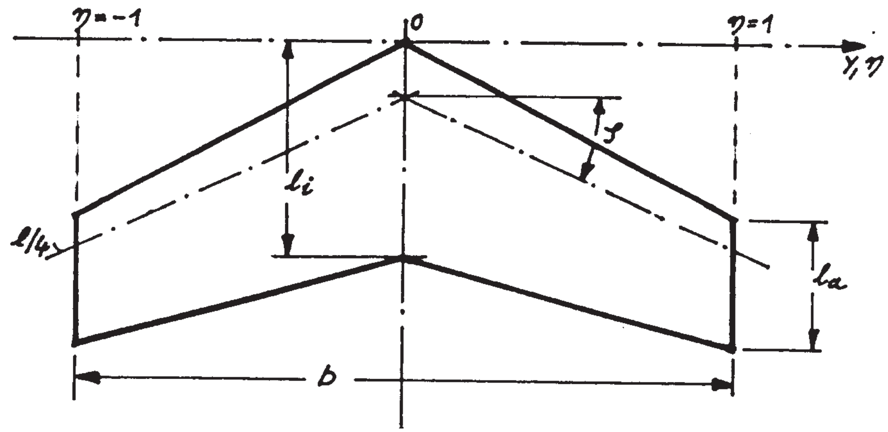
<u>Some design parameters of the flying wing</u>

The determination of $c_{m0p}$ and $c_{m0s}$ belongs to the most important work during the design of a flying wing model. In this context we must become acquainted with some important design parameters.

In order to keep the variety of possible wing plan forms in feasible limits, we want to confine ourselves to linear twisted swept tapered wings. This is the basic plan form of the flying wing.

Such a wing is given by the following parameters:

sweep angle $\gamma°$, usually measured at the quarter chord line,




Picture 5

taper $\tau = l_a / l_i$ <eqn. 10>

with $l_i$ = chord length at the wing root, $l_a$ = chord length at the wing tip,

aspect ratio $\Lambda = b^2 / F$ <eqn. 11>

with b = wing span, F = wing area.

See Picture 5.

Next to that some more relations can be given which are useful for further calculations. Their derivation is not given here, those who want can easily do these derivations of their own. It holds

wing area $F = \frac{1+\tau}{2} \cdot b \cdot l_i$ <eqn. 12>

aspect ratio $\Lambda = \frac{2}{1+\tau} \cdot \frac{b}{l_i}$ <eqn. 13>

reference chord length $l_\mu = l_i \cdot \frac{2}{3} \cdot \frac{1+\tau+\tau^2}{1+\tau}$ <eqn. 14>

function of chord length $l = l_i\left[1-(1-\tau)\frac{2y}{b}\right]$ <eqn. 15>

In aerodynamic calculations usually a dimensionless coordinate $\eta$ in span direction is used, this reduces the formulae to a great extent. $\eta$ simply denotes the distance of a point from the center divided by the half span:

$$\eta = \frac{y}{b/2} \qquad \text{<eqn. 16>}$$

The wing covers the values $\eta$ from $\eta$ = -1 at the left tip to $\eta$ = 0 at the center to $\eta$ = 1 at the right tip.

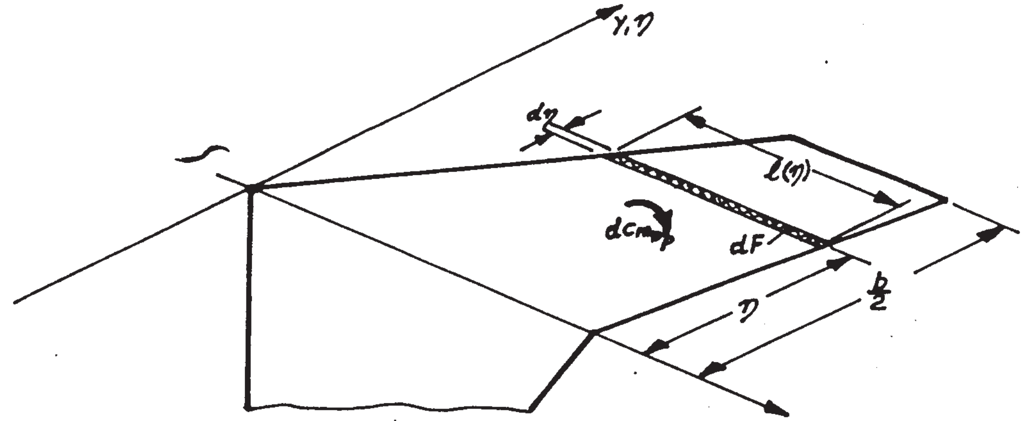
Thus the function of the chord length (eqn. 15) can easier be written as

$$l = l_i \left[1 - (1 - \tau) \cdot \eta\right] \qquad \text{<eqn. 17>}$$

In what follows the usual notation for dependent variables, for instance $c_{m0}$ ($\eta$), l ($\eta$) and so on is used. This is to express that $c_{m0}$ or l and so on are not constant but variable values, which change their values along the coordinate $\gamma$ or $\eta$ in span direction.

It is necessary that the following uses some mathematics. Those who don't want to read this can overlook it and go on reading the results. The derivations should not be omitted here, because they give to interested people the way to the results, but the derivations are limited here.

Determination of the airfoil zero moment component $c_{m0p}$




Picture 6

Now we want to determine the component $c_{m0p}$ of the zero moment, whose origin we already got to know before.

An element of the wing (see Picture 6) has the contribution

$$dc_{m0p} = c_{mp}(\eta) \cdot l(\eta) \cdot dF = c_{mp}(\eta) \cdot l^2(\eta) \cdot \frac{b}{2} \cdot d\eta \qquad \text{<eqn. 18>}$$

Herein $c_{mp}(\eta)$ is the zero moment value as given in airfoil data.

We get the coefficient of the whole wing by summing up the contributions of all the elements of the wing and then dividing by the wing area and by the reference wing chord:

$$c_{m0p} = \frac{1}{F \cdot l_\mu} \int_{-1}^{+1} c_{mp}(\eta) \cdot l^2(\eta) \cdot \frac{b}{2} \cdot d\eta \qquad \text{<eqn. 19>}$$

Now let's suppose that the root airfoil linearily varies into the tip airfoil, and that the coefficient of the zero moment linearily changes from the value at the wing root to the value at the wing tip.

$$c_{mp}(\eta) = c_{mi} - (c_{mi} - c_{ma}) \cdot \eta \qquad \text{<eqn. 20>}$$

where $c_{mi}$ = zero moment coefficient at the wing root
$C_\alpha$ = zero moment coefficient at the wing tip

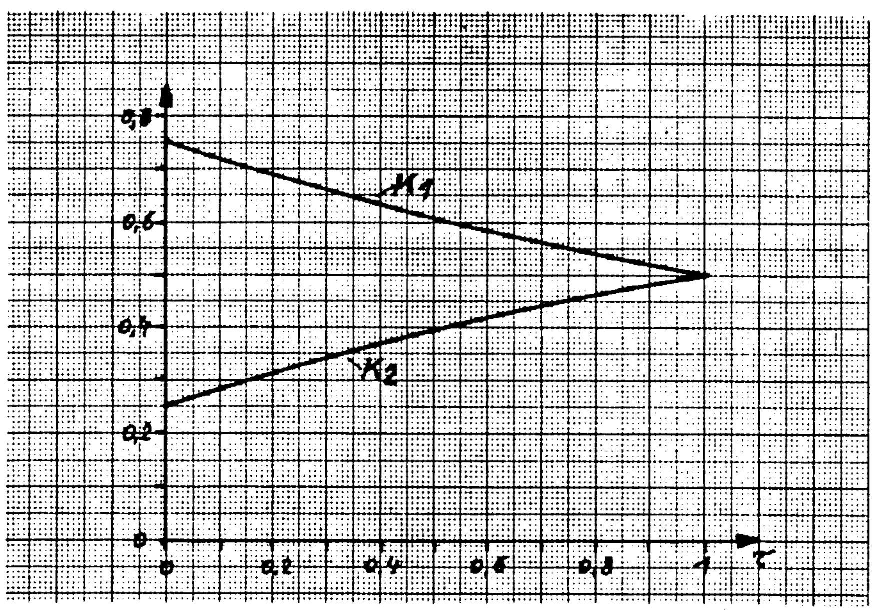
Now we insert the terms (eqn. 20) and (eqn. 17) into eqn. 19, and we can save some calculating work by summing up only over one wing half span and doubling the result. Then we yield from eqn. 19:

$$c_{m0p} = \frac{b \cdot l_i^2}{F \cdot l_\mu} \int_0^1 \left[c_{mi} - (c_{mi} - c_{ma})\eta\right]\left[1 - (1-\tau)\cdot\eta\right]^2 \cdot d\eta$$ <eqn. 21>

The determination of this integral is not difficult, but takes some time and should be left out here. The result is

$$c_{m0p} = \frac{b \cdot l_i^2}{12 \cdot F \cdot l_\mu}\left[c_{mi}(3 + 2\tau + \tau^2) + c_{ma}(1 + 2\tau + 3\tau^2)\right]$$ <eqn. 22>

Using the equations (12) to (14) this expression can be simplified and finally yields




Picture 7

$$c_{m0p} = K_1 \cdot c_{mi} + K_2 \cdot c_{ma}$$ <eqn. 23>

where $K_1$ and $K_2$ are influence factors that are dependent only from the plan form (i.e. from the taper $\tau$, because we confined ourselves to the trapezoid wing):

$$K_1 = \frac{1}{4} \cdot \frac{3 + 2\tau + \tau^2}{1 + \tau + \tau^2}$$ <eqn. 24>

$$K_2 = \frac{1}{4} \cdot \frac{1 + 2\tau + 3\tau^2}{1 + \tau + \tau^2}$$ <eqn. 25>

Furthermore it holds

$$K_1 + K_2 = 1$$ <eqn. 26>

as can easily be shown.

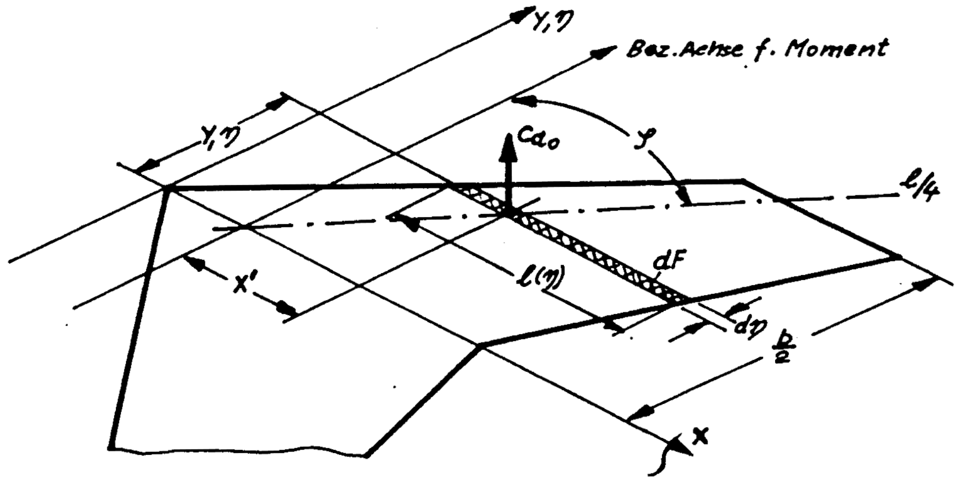
The factors $K_1$ and $K_2$ are shown in Picture 7 as functions of $\tau$.

In the special case $\tau = 1$ (rectangular wing) it holds $K_1 = K_2 = 0.5$, and $c_{m0p}$ is determined by simply taking the mean of the coefficients of root airfoil and tip airfoil.

With eqn. (23) to eqn. (26) we have found the formulae for the determination of the first component of the zero moment.

<u>Determination of the twist zero moment component $c_{m0s}$</u>

As we have already seen, this part comes from the distribution of lift forces along the longitudinal direction, whereas the sum of the lift forces itself is zero. Thus we have here a so called "free" moment,




Picture 8

for the determination of it we can use an arbitrarily chosen axis.

The calculation becomes easiest if we choose an axis that goes through the intersection point of the x axis and the quarter chord line. Furthermore, we use the usual assumption that the resulting lift force of a wing element acts at its quarter chord point, see Picture 8.

A wing element at the distance y from the wing root gives the following contribution to the moment:

$$dc_{mo_S} = -x'(y)\cdot c_{a_0}(y)\cdot dF \qquad \text{<eqn. 27>}$$

Here it holds

$$x' = y\cdot tg\varphi = \frac{b}{2}\cdot\eta\cdot tg\varphi \qquad \text{<eqn. 28>}$$

and

$$dF = l(\eta)\cdot dy = l(\eta)\cdot\frac{b}{2}\cdot d\eta \qquad \text{<eqn. 29>}$$

To remind you that the calculation is done for the zero lift distribution the coefficient c-a has got the index 0.

The coefficient of the whole wing results from summing up the contributions of all the wing elements and by division by the wing area and the reference chord length. As before, we sum up only over one wing half and then double the result.

Thus we get

$$c_{mo_S} = -\frac{2}{F\cdot l_\mu}\int_0 \frac{b}{2}\cdot\eta\cdot tg\varphi\cdot c_{a_0}(\eta)\cdot l(\eta)\cdot\frac{b}{2}\cdot d\eta \qquad \text{<eqn. 30>}$$

This expression can still be simplified, we get

$$c_{mo_S} = -\frac{\Lambda\cdot tg\varphi}{2\cdot l_\mu}\int_0^1 c_{a_0}(\eta)\cdot l(\eta)\cdot\eta\cdot d\eta \qquad \text{<eqn. 31>}$$

At this point we have the “terminal” for simple calculations, because in the integral we find the expression $c_{\alpha 0}(\eta) \cdot l(\eta)$, which denotes the lift distribution at zero lift, but which we do not know.

It is possible to insert eqn. (17) for $l(\eta)$ in eqn. (31), but this doesn’t help, because $c_{\alpha 0}(\eta)$ is still unknown.

Now we have the problem to determine the zero lift distribution, next to that we can calculate the desired $c_{m0s}$ by using eqn. (31). To do that, real data of the wing is required.

Now it is possible to do this task for a large number of wings and then to unify the results into a formula being as simple as possible. This formula would permit us to determine the zero moment of twist without a calculation of the zero lift distribution at least for the wings used in the formula.

This will be done next. We will see that it is possible to make such a formula for our family of swept trapezoid wings.

For the determination of the lift distribution or circulation distribution there exist some methods for more than 50 years. Of all these the Multhopp method (named after its inventor) is the best known and most applicable one, although the numerical effort is still considerable. It is described for instance in [ 1 ].

A special problem in the case of a flying wing is that the original Multhopp method is valid only for the non swept wing. There exist also methods for the swept wing, but most of them have the drawback not to be programmable at a micro computer.

Here a method given by D. Kuechemann [ 2 ] is used to calculate the swept wing. This method uses the idea to make certain changes at the local lift derivations before a Multhopp type calculation is done. The amount of change depends on the wing planform and on the local point itself. It is not possible to go into the details here.

The calculations show that for swept wings with not too small aspect ratios $\Lambda$ = 6 >) and moderate sweep ($\gamma$ <= 15 degrees) the corrections are small. By the way, this observation was made earlier [ 3 ]. This means that for a wing with small sweep it is permitted to calculate the lift distribution at first like for a non swept wing and than turn this distribution with the sweep angle backwards.

The correction also yields the well known “middle effect” of a swept wing. This is a more or less pronounced loss (when having backward sweep) of lift at the wing root.

The author has programmed the Multhopp method together with the Kuechemann correction for an Apple ][ micro computer and has calculated a large number of zero lift distributions with it.

In these calculations the parameters $\gamma$, $\Lambda$, $\tau$, $\alpha_S$ ( = twist between zero lift angle of attack of root airfoil and tip airfoil) were varied in the region of practical interest.

The following values are assumed:

sweep angle $\gamma$: 10, 20,30 degrees

aspect ratio. $\eta$: 5,10,15

taper tau : 1.0, 0.75, 0.50, 0.25, 0

twist $\alpha_S$: -3, -6, -9, -12 degrees

Of course the program determines not only the lift distribution, but also our aim, the zero moment component $c_{m0s}$ from eqn. (31).

In Table 1 the direct calculation results are summarized.

<u>Evaluation of calculated data</u>

From Table 1 we can see: $c_{m0s}$ is proportional to the twist angle $\alpha_S$, $c_{m0s}$ is proportional to the sweep angle $\gamma$. The latter is sure no longer valid for larger sweep, but in the here interesting region $\gamma$ < 30 degrees the error makes only a negligible difference. Thus we can write

$$c_{m0s} = K_3(\tau, \Lambda) \cdot \gamma \cdot \alpha_S$$ <eqn. 32>

Here $K_3$ is a factor depending on $\tau$ and $\Lambda$. In Table 2 the values of $K_3$ are summarized, furthermore in Picture 9 $K_3$ is shown as function of $\tau$ with parameter $\Lambda$.

$100 \cdot c_{m0s}$ :

| | $\Lambda = 5$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\varphi = 10°$ | | | | $\varphi = 20°$ | | | | $\varphi = 30°$ | | | |
| $\tau$ \ $\alpha_s$ | -3° | -6° | -9° | -12° | -3° | -6° | -9° | -12° | -3° | -6° | -9° | -12° |
| 1.00 | 0.420 | 0.860 | 1.29 | 1.73 | 0.860 | 1.73 | 2.60 | 3.44 | 1.30 | 2.61 | 3.96 | 5.25 |
| 0.75 | 0.420 | 0.870 | 1.29 | 1.73 | 0.860 | 1.72 | 2.59 | 3.43 | 1.30 | 2.62 | 3.93 | 5.30 |
| 0.50 | 0.420 | 0.840 | 1.24 | 1.67 | 0.820 | 1.66 | 2.50 | 3.34 | 1.26 | 2.53 | 3.80 | 5.09 |
| 0.25 | 0.370 | 0.740 | 1.10 | 1.47 | 0.730 | 1.48 | 2.23 | 2.99 | 1.13 | 2.26 | 3.37 | 4.51 |
| 0 | 0.250 | 0.30 | 0.75 | 1.00 | 0.520 | 1.01 | 1.50 | 2.00 | 0.74 | 1.51 | 3.02 | 3.03 |

| | $\Lambda = 10$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\varphi = 10°$ | | | | $\varphi = 20°$ | | | | $\varphi = 30°$ | | | |
| $\tau$ \ $\alpha_s$ | -3° | -6° | -9° | -12° | -3° | -6° | -9° | -12° | -3° | -6° | -9° | -12° |
| 1.00 | 1.20 | 2.44 | 3.68 | 4.89 | 2.41 | 4.81 | 7.37 | 9.71 | 3.66 | 7.28 | 10.8 | 14.6 |
| 0.75 | 1.24 | 2.43 | 3.70 | 4.89 | 2.40 | 4.89 | 7.33 | 9.78 | 3.67 | 7.21 | 10.9 | 14.6 |
| 0.50 | 1.20 | 2.38 | 3.51 | 4.76 | 2.30 | 4.72 | 6.99 | 9.35 | 3.54 | 7.02 | 10.5 | 14.0 |
| 0.25 | 1.05 | 2.06 | 3.13 | 4.17 | 2.02 | 4.16 | 6.15 | 8.21 | 3.12 | 6.18 | 9.24 | 12.3 |
| 0 | 0.67 | 1.34 | 2.02 | 2.70 | 1.33 | 2.71 | 4.05 | 5.35 | 2.01 | 3.92 | 5.92 | 8.00 |

| | $\Lambda = 15$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\varphi = 10°$ | | | | $\varphi = 20°$ | | | | $\varphi = 30°$ | | | |
| $\tau$ \ $\alpha_s$ | -3° | -6° | -9° | -12° | -3° | -6° | -9° | -12° | -3° | -6° | -9° | -12° |
| 1.00 | 2.21 | 4.35 | 6.41 | 8.69 | 4.30 | 8.39 | 12.7 | 16.9 | 6.21 | 12.7 | 18.9 | 25.1 |
| 0.75 | 2.12 | 4.36 | 6.50 | 8.66 | 4.28 | 8.35 | 12.6 | 17.0 | 6.21 | 12.7 | 18.9 | 25.1 |
| 0.50 | 2.02 | 4.06 | 6.22 | 8.24 | 4.14 | 8.14 | 12.1 | 16.1 | 5.89 | 11.9 | 18.1 | 24.0 |
| 0.25 | 1.77 | 3.57 | 5.38 | 7.16 | 3.60 | 7.14 | 10.7 | 14.2 | 5.18 | 10.5 | 15.7 | 20.8 |
| 0 | 1.14 | 2.33 | 3.48 | 4.58 | 2.23 | 4.57 | 6.78 | 9.05 | 3.47 | 6.76 | 10.1 | 13.5 |

Table 1: The zero moment component $c_{m0s}$ from eqn. (31)

$10^4 \cdot K_3$ :

| $\tau$ \ $\Lambda$ | 5 | 10 | 15 |
|---|---|---|---|
| 1.00 | -1.45 | -4.07 | -7.06 |
| 0.75 | -1.46 | -4.07 | -7.10 |
| 0.50 | -1.40 | -3.91 | -6.77 |
| 0.25 | -1.24 | -3.44 | -5.89 |
| 0 | -0.884 | -2.23 | -3.77 |

Table 2: The values of $K_3$ summarized

If we omit the case $\tau = 0$ which is of less practical interest, a further reduction of data is possible: Using an exponent approach for the dependency from $\Lambda$ we can reduce the three functions to only one.

We write

$$c_{m0s} = f(\tau) \cdot \Lambda^n \cdot \varphi \cdot \alpha_s \qquad \text{<eqn. 33>}$$

where the exponent n is determined using the regression calculus. The value of n is 1.42 for $\tau = 0.25$ and 1.45 for $\tau = 1$ . Using a mean value of 1.43 the three functions simplify to only one function if we need only the here given accuracy of calculation and drawing, all this is valid for 0.25 <= $\tau$ <=1

Thus we can write

$$c_{m0s} = K_4(\tau) \cdot \Lambda^{1,43} \cdot \varphi \cdot \alpha_s \qquad \text{<eqn. 34>}$$

| $\tau$ | 1.00 | 0.75 | 0.50 | 0.25 |
|---|---|---|---|---|
| $10^4 \cdot K_4$ | 0.148 | 0.148 | 0.142 | 0.125 |

Table 3: The factor $K_4(\tau)$

The factor $K_4(\tau)$ is given in Table 3 and in Picture 9. In most of practical purposes we can use one more simplification by assuming a constant mean value of $K_4 = -1.4 \cdot 10^{-5}$ for $K_4(\tau)$. This approximate value is also shown in Picture 9.

If the dependency from tau should be taken into account, the use of an approximate function is possible. Useful is for instance

$$K_4(\tau) = \frac{8{,}05 \cdot 10^{-7}}{\tau} - 1{,}57 \cdot 10^{-5}$$ <eqn. 35>

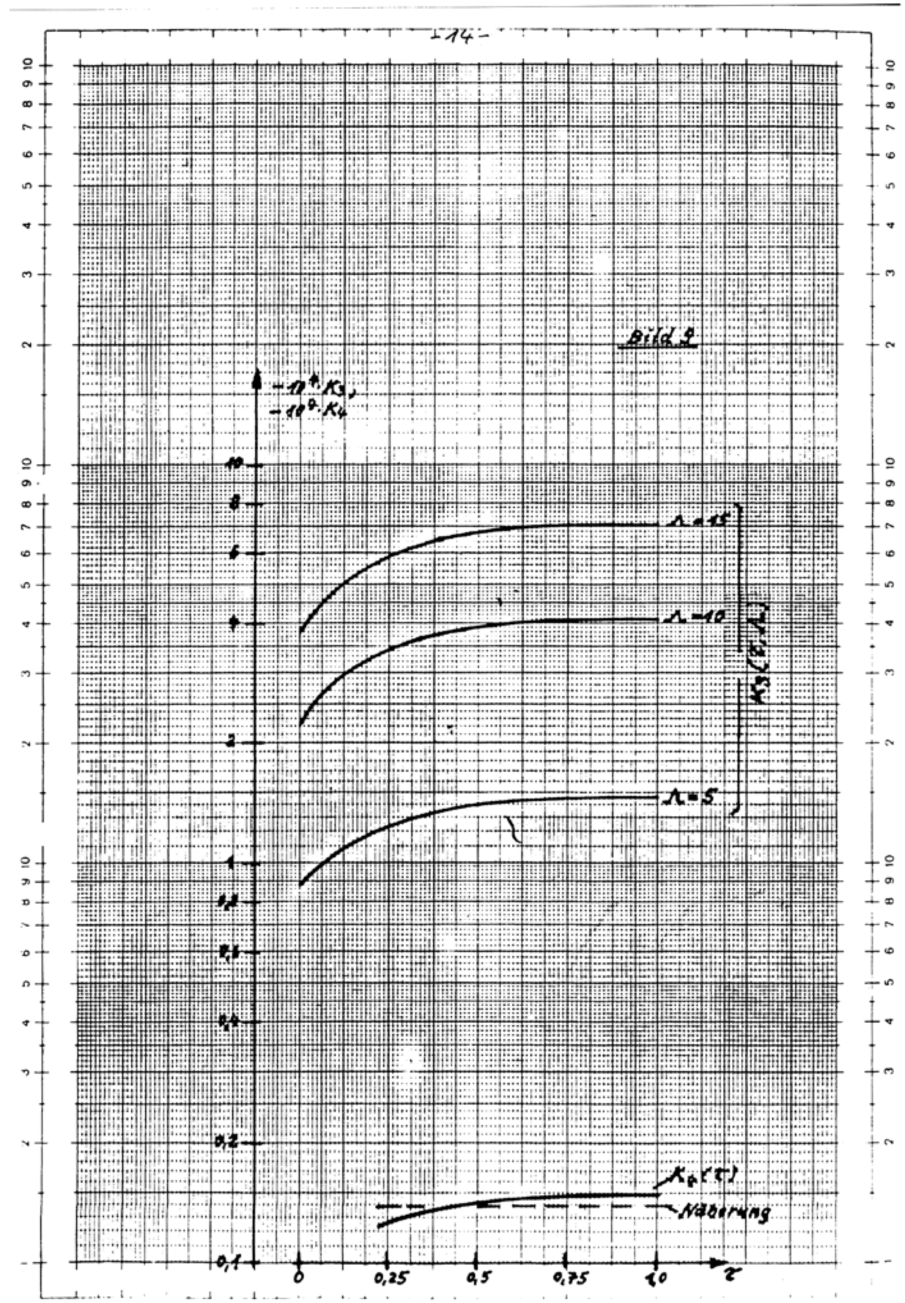
Now we have found the formula for the determination of the twist zero moment coefficient:

$$c_{m0S} = \left(\frac{8{,}05 \cdot 10^{-7}}{\tau} - 1{,}57 \cdot 10^{-5}\right) \cdot \Lambda^{1{,}43} \cdot \gamma \cdot \alpha_S$$ <eqn. 36>

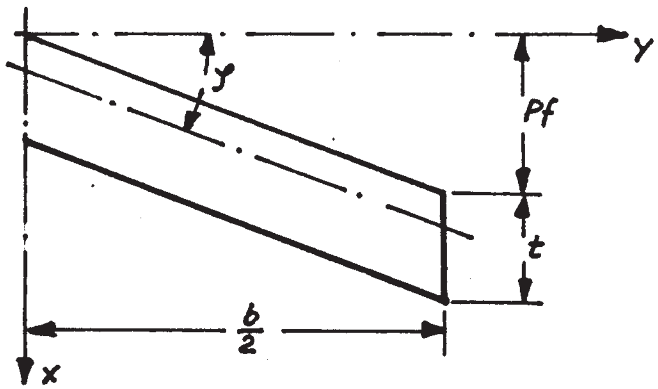
or

$$c_{m0S} = -1{,}40 \cdot 10^{-5} \cdot \Lambda^{1{,}43} \cdot \gamma \cdot \alpha_S$$ <eqn. 37>

The angles $\gamma$ and $\alpha_S$ have to be inserted in degrees, for normal twist (a.o.a. is smaller at the tips) $\alpha_S$ must be inserted negative. Furthermore you are reminded that $\alpha_S$ is measured between the directions of the angle of attack at zero lift of the root airfoil and the tip airfoil. So, in the practical design of twist the difference between the directions of the angle of attack at zero lift of the root airfoil and the tip airfoil must be subtracted or added.




Picture 9




Picture 10

In the following the eqn. (37) is used for more clarity, but who wants can use eqn. (36) instead. With the eqns. (9), (23) to (26) and (37) we have all we need for the determination of the longitudinal moment of a linear twisted swept trapezoid wing, assuming the location of the C.G. is known.

If we insert all this into eqn. (8), we get:

$$-1{,}40\cdot 10^{-5}\cdot\Lambda^{1{,}43}\cdot\varphi\cdot\alpha_s + K_1\cdot c_{mi} + K_2\cdot c_{m\alpha} = \bar{c}_a\cdot STM$$

<eqn. 38>

This formula can be solved for $\alpha_S$ and yields

$$\alpha_s = \frac{K_1\cdot c_{mi} + K_2\cdot c_{m\alpha} - \bar{c}_a\cdot STM}{1{,}40\cdot 10^{-5}\cdot\Lambda^{1{,}43}\cdot\varphi}$$

<eqn. 39>

With the help of this formula the required twist angle can be calculated.

Next to this it is also possible to solve eqn. (38) for other variables, for instance for $c_a$-overline, in order to determine the flight attitude if the twist is given.

Below we will see the practical use of the formulae in examples.

Comparison to the "Eppler formula"

In [ 4 ] a formula for the determination of the twist of a linear twisted swept wing is published by R. Eppler:

$$\alpha_s = 190\cdot\frac{-\bar{c}_{m0} + STM}{Pf/t}$$

<eqn. 40>

The formula is only valid for a wing with constant chord length, pf and t are defined according to Picture 10. $c_{m0}$-overline is the mean value of the zero moment coefficients of the root airfoil and tip airfoil.

This formula is to be compared to the formula eqn. (39) which was developed here. To do so, eqn. (40) is somehow transformed.

It holds

$$Pf = \frac{b}{2}\cdot tg\,\varphi$$

<eqn. 41>

If we restrict ourselves to small sweep ($\gamma$ <= 30 degrees), it holds approximately

$$Pf = \frac{b}{2}\cdot 0{,}0182\cdot\varphi = 9{,}099\cdot 10^{-3}\cdot b\cdot\varphi$$

<eqn. 42>

(with phi in degrees)

Furthermore for a non tapered wing is lambda=b/t, so we get from eqn. (42)

$$Pf/t = 9{,}099\cdot 10^{-3}\cdot\Lambda\cdot\varphi$$

<eqn. 43>

If we inset this into eqn. (40) and move the factor 190 into the denominator, the "Eppler formula" becomes

$$\alpha_s = \frac{-\bar{c}_{m0} + STM}{4{,}79\cdot 10^{-5}\cdot\Lambda\cdot\varphi}$$

<eqn. 44>

Now it is more similar to our eqn. (39).

$c_{m0}$-overline is the same as our $c_{m0p}$ which in the case of a rectangular wing also simplifies to the mean value of the coefficients of the root airfoil and tip airfoil.

In the “Eppler formula” the twist angles are positive defined in the usual sense, i.e. opposite to our definition. This is an arbitrary definition, so we can change the sign of the numerator of eqn. (44) in order to reach accordance to our definition.

For the reason of the following comparison it is wise to put the stability measure STM in front of the fraction. Then the “Eppler formula” writes

$$\alpha_s = STM \cdot \frac{\frac{c_{m0p}}{STM} - 1}{4{,}79 \cdot 10^{-5} \cdot \Lambda \cdot \varphi}$$

<eqn. 45>

Our eqn. (39) is converted to the same shape, further we insert the exact value of K-4 at $\tau$ = 1 instead of the approximate value: $K_4 = -1.48 \cdot 10^{-5}$. Then our formula is

$$\alpha_s = \frac{\frac{c_{m0p}}{STM} - \bar{c}_a}{1{,}48 \cdot 10^{-5} \cdot \Lambda^{1{,}43} \cdot \varphi}$$

<eqn. 46>

Now lets look at eqns. (45) and (46). In eqn. (45) $c_a$-overline does not appear, we can suppose that the formula is valid for a typical mean value of $c_a$-overline for a flying wing model. In the “Eppler formula” $\alpha_S$ is reciprocal proportional to $\Lambda$, in our formula it is reciprocal proportional to $\Lambda$ to the power of 1.43.

Let’s now constitute the relation of the alpha - s value from our formula (46) to that from the “Eppler formula” (45). The relation is called (small, not capital) lambda:

$$\lambda = \frac{\alpha_{s(46)}}{\alpha_{s(45)}} = \underbrace{\frac{\frac{c_{m0p}}{STM} - \bar{c}_a}{\frac{c_{m0p}}{STM} - 1}}_{\equiv A} \cdot \frac{3{,}24}{\Lambda^{0{,}43}}$$

<eqn. 47>

In the ideal case both formulae should give the same result, i.e. $\lambda$ should become 1.0.

In eqn. (47) the factor A is annoying, we can not simplify it becaue it is dependend on $c_a$-overline, STM, $c_{m0p}$ of the given layout.

In the special case $c_a$-overline = 1 the fraction could be reduced and we would get A = 1. But unfortunately $c_a$-overline = 1 is not a typical case for flying wing models. Here $c_a$-overline would be about 0.6 to 0.8 at best glide angle or best sink rate.

We had

$$A = \frac{\frac{c_{m0p}}{STM} - \bar{c}_a}{\frac{c_{m0p}}{STM} - 1}$$

<eqn. 48>

and can now think about which values A would have in practical cases: $c_{mOp}$ is normally negative or equal to zero, in other case we would not build a twisted swept wing. In the limit case $c_{m0p}$ = 0 we get A = $c_a$-overline.

For other (i.e. negative values) of $c_{m0p}$ or $c_{m0p}$ / STM the variable A is in the interval from $c_a$-overline to 1, i.e. we get

$$\bar{c}_a \leq A \leq 1$$

<eqn. 49>

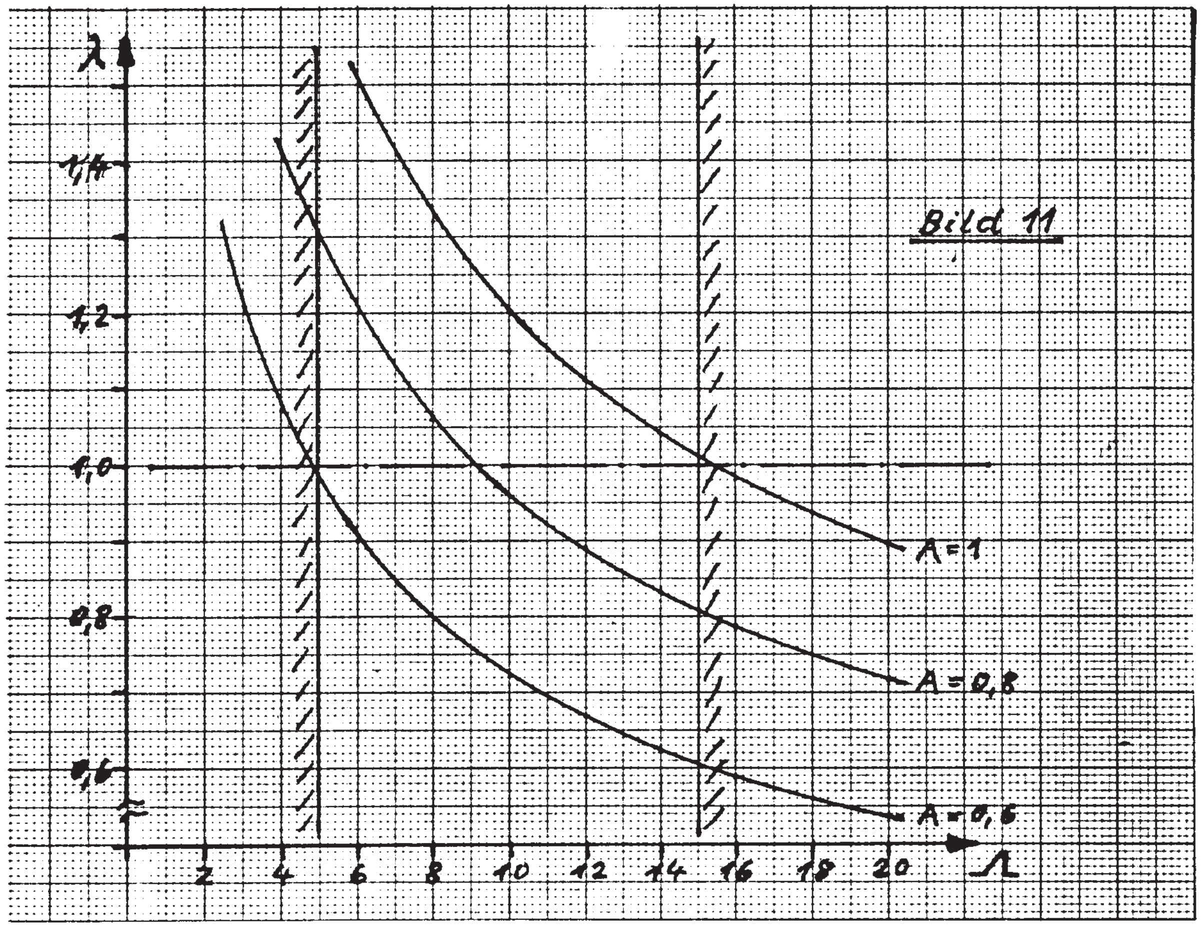
In Picture 11 (next page) $\lambda$ is shown as function of $\Lambda$ as indicated in eqn. (47) with the parameter A = 0.6, 0.8, 1.0.

We see: Dependent on A both formulae give same results ($\lambda$ = 1) for different aspect ratios $\Lambda$.

$\lambda$ = 1 for

| A | 0.6 | 0.8 | 1.0 |
|---|---|---|---|
| $\Lambda$ | 4.6 | 9 | 15 |

In practical realized models A is supposed to be near 0.8. In this case both formulae would result in the same twist angle for an aspect ratio equal to 9.




Picture 11

At smaller aspect ratios our equation (39) yields larger $\alpha_S$, at $\Lambda > 9$ it yields smaller $\alpha_S$ than the "Eppler formula." The differences are up to 20 %.

In Picture 11 the practical interesting interval of $\Lambda$ is shown (about $5 < \Lambda < 15$). We see that at A = 0.8 the "Eppler formula" is right in the center. This proves that it is well suitable as a simple rule of thumb.

For a "high lift" concept (A = 1) it gives $\alpha_S$ to small (in the extreme until up to 50%). For a "high speed" concept (A = 0.6) it gives $\alpha_S$ too large in the extreme until up to 40%).

So the "Eppler formula" should be looked upon as a fast formula for first information and average designs. The formula developed herein permits a more detailed calculation at the cost of some more calculation work.

Some examples

The following example calculations show the application of the derived formula. They don't tell anything about the functionality or flight performance of the assumed designs.

Example 1

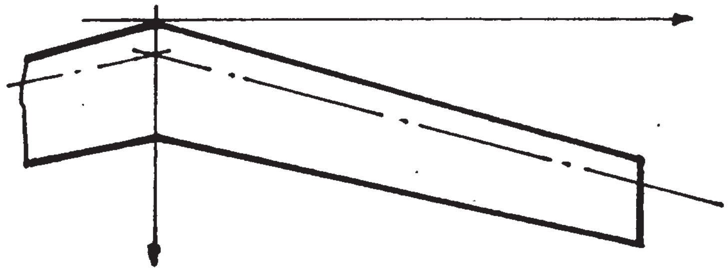
A "fast" design with symmetrical airfoils all over the wing. The used airfoil (NACA 0009) has $c_{amax}$ =0.7, so the design $c_a$-overline is assumed to be 0.4, STM = 0.07. Sweep is 15 degrees.

Required twist $\alpha_S$ = -5 degrees

Example 2

For this example an airfoil with higher $c_{\underline{amax}}$ is assumed at the wing root (Clark Y 10%), which passes over to a symmetrical airfoil at the wing tip (NACA 0009). The aspect ratio is larger than in the first example, and so is the sweep (20 degrees). The taper is chosen to $\tau$ = 1 (swept rectangular wing). $c_a$-overline = 0.7 and STM = 0.1 are assumed.

Required twist $\alpha_S$ = - 12 degrees



$b = 2500$ mm
$l_i = 300$ mm
$l_a = 200$ mm

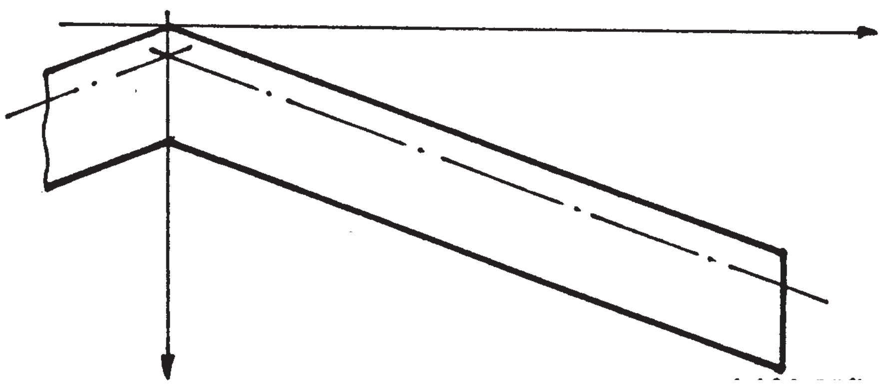
$\tau = \frac{l_a}{l_i} = 0.67$

$F = \frac{l_i + l_a}{2} \cdot b = 62.5 \text{ dm}^2$

$\Lambda = \frac{b^2}{F} = 10$

$$\alpha_s = \frac{-\bar{c}_a \cdot STM}{1{,}4 \cdot 10^{-5} \cdot \Lambda^{1{,}43} \cdot \varphi} = \frac{-0{,}4 \cdot 0{,}07}{1{,}4 \cdot 10^{-5} \cdot 10^{1{,}43} \cdot 15} = -4{,}95^\circ \approx \underline{\underline{-5^\circ}}$$

Example 1



$b = 3200$ mm
$l_i = l_a = 300$ mm
$\tau = 1$

$F = l \cdot b = 96 \text{ dm}^2$

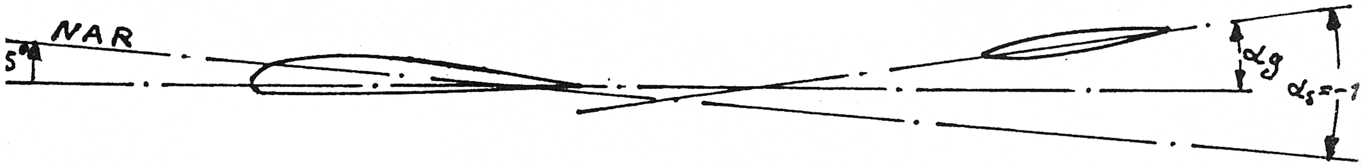
$\Lambda = \frac{b^2}{F} = 10.7$

$\varphi = 20^\circ$

$$= \frac{K_1 \cdot C_{mi} + K_2 \cdot C_{ma} - \bar{c}_a \cdot STM}{1{,}4 \cdot 10^{-5} \cdot \Lambda^{1{,}43} \cdot \varphi} = \frac{0{,}5 \cdot (-0{,}059) + 0{,}5 \cdot 0 - 0{,}7 \cdot 0{,}1}{1{,}43 \cdot 10^{-5} \cdot 10{,}7^{1{,}43} \cdot 20}$$

$$= \frac{-0{,}0295 - 0{,}07}{0{,}0083} = -11{,}99^\circ \approx \underline{\underline{-12^\circ}}$$

Example 2




Picture A

This calculated $\alpha_S$ is measured between the directions of the zero lift angles. The wing root airfoil Clark Y 10% has a zero lift angle of -4.5 degrees, this angle has to be subtracted from the calculated twist, see Picture A.

The geometric twist which is to build into the model is alpha-a = -7.5 degrees.

$$\alpha_g = \alpha_s - \alpha_0 = -12 - (-4{,}5) = \underline{\underline{-7{,}5^\circ}}$$

<u>Example 3</u>

In this example the well known "Eppler airfoil transition" E174 root / E182 (tip) is used in a wing with much taper and small aspect ratio.

$c_a$-overline = 0.6 and STM = 0.08 are assumed.

From Picture 7 we see that for $\tau$ = 0.4 we get $K_1$ = 0.63, $K_2$ = 0.37.

We get

Required twist $\alpha_S$ = -19.1 degrees

The directions of the zero lift angles already have a difference of 3.3 degrees, so the calculated twist angle has to be reduced to $\alpha$g = -16.8 degrees.

Anyway, there is still a very high value of 16.8 degrees required twist. We can foresee that the lift distribution of this wing will not be too good under practical conditions.

Let us now ask for the reasons of the high required twist:

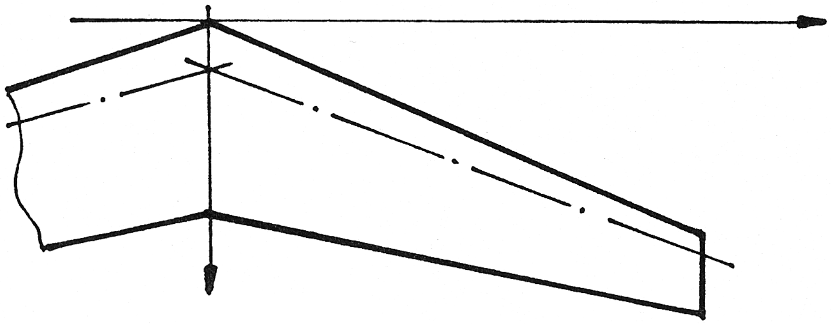
1. By working together much taper (large chord at the root) and large negative zero moment of the root airfoil a big negative $c_{m0p}$ arises, which can not be compensated enough by the wing tip.

2. The aspect ratio 7.43 is rather small, but therefore this model will hardly have flutter problems.

3. We assumed a rather high STM (0.08) and a rather high $c_a$-overline (0.6).

If the model could be flown with STM = 0.04 and if we had assumed a design $c_a$-overline of 0.5, so the required geometrical twist would have been only 10.8 degrees.

Despite of this we can learn from this example, that the combination of small aspect ratio with much taper and with a root profile having a large negative zero moment coefficient should be avoided if possible.



$b = 2600$ mm
$l_i = 500$ mm
$l_a = 200$ mm

$\tau = \frac{l_a}{l_i} = 0.4$

$F = \frac{l_i + l_a}{2} \cdot b = 91 \text{ dm}^2$

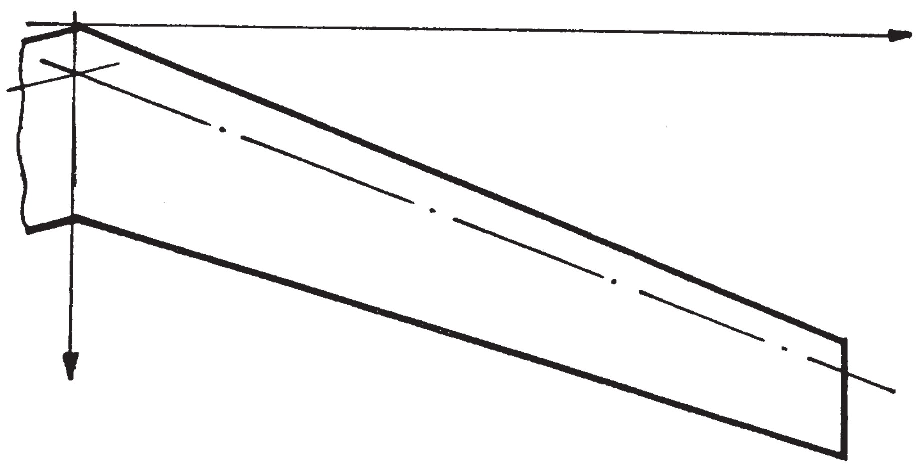
$\varphi = 20^\circ$

$\Lambda = \frac{b^2}{F} = 7{,}43$

$$\alpha_S = \frac{K_1 \cdot c_{mi} + K_2 \cdot c_{ma} - \bar{c}_a \cdot STM}{1{,}4 \cdot 10^{-5} \cdot \Lambda^{1{,}43} \cdot \varphi} = \frac{0{,}63 \cdot (-0{,}083) + 0{,}37 \cdot 0{,}007 - 0{,}6 \cdot 0{,}08}{1{,}4 \cdot 10^{-5} \cdot 7{,}43^{1{,}43} \cdot 20}$$

$$= \frac{-0{,}0497 - 0{,}048}{0{,}00493} = \underline{\underline{-19{,}1^\circ}}$$

Example 3



$b = 4000$ mm
$l_i = 500$ mm
$l_a = 300$ mm

$\tau = \frac{l_a}{l_i} =$

$F = \frac{l_i + l_a}{2} \cdot b = 160 \text{ dm}^2$

$\Lambda = \frac{b^2}{F} = 10$

$\varphi = 20^\circ$

$$\alpha_S = \frac{0{,}58 \cdot (-0{,}083) + 0{,}43 \cdot 0{,}007 - 0{,}6 \cdot 0{,}08}{1{,}4 \cdot 10^{-5} \cdot 10^{1{,}43} \cdot 20} = \frac{-0{,}0451 - 0{,}048}{0{,}00754} = \underline{\underline{-12{,}3^\circ}}$$

Example 4

Example 4

We now improve the data of Example 3. We choose a larger aspect ratio and less taper. The (here arbitrarily chosen) new data present already a "big flying wing."

Airfoil data as in example 3.

From Picture 7 we see that for $\tau$ = 0.6 we get $K_1$ = 0.58, $K_2$ = 0.43.

We get

Required twist $\alpha_S$ = -12.3 degrees

After consideration of the different directions of the zero lift angles we get

$$\alpha_g = -12{,}3 - (-3{,}3) = \underline{\underline{-9^\circ}}$$

$\alpha_g$ = -9 degrees.

Assuming that STM can be reduced to 0.05, we get $\alpha_S$ = -9.96 degrees and $\alpha_g$ = -6.7 degrees.

Example 5

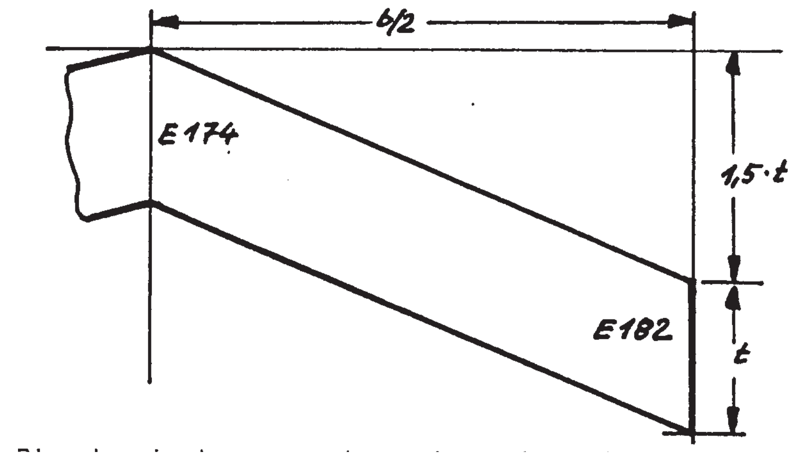
In this last example we are once more occupied with the "Eppler airfoil transition" E174 (root) / E182 (tip). This transition is published for instance in [ 5 ]; it is very often used in practice and thus deserves special attention.

In [ 5 ] there is given a wing planform together with the transition, but the plan form is not given clear, because there is no relation between the half span b/2 and the other dimensions.

For this transition it is said, that with a geometrical twist of only 2 degrees you get a longitudinal stable wing. In contrast to this it is known from many practical reports that at least 4 degrees of geometric twist must be built in.

This is why we want to deal with this transition in detail, but we want to restrict ourselves to the case of a wing without taper.

The formula for the required twist is




Example 5

$$\alpha_S = \frac{c_{m0p} - \bar{c_a} \cdot STM}{1{,}48 \cdot 10^{-5} \cdot \Lambda^{1{,}43} \cdot \gamma}$$

with $$c_{m0p} = K_1 \cdot c_{m_i} + K_2 \cdot c_{m_a}$$

Using the data of E174 and E182 and with $\tau$ = 1 we get $c_{m0p}$ = -0.038 and

$$\alpha_S = \frac{-0{,}038 - \bar{c_a} \cdot STM}{1{,}48 \cdot 10^{-5} \cdot \Lambda^{1{,}43} \cdot \gamma}$$

Now we assume a geometric twist $\alpha_g$ and determine which combination of twist and sweep is necessary in order to get moment equilibrium. We solve our formula for $\Lambda^{1.43}$ times $\gamma$

$$\Lambda^{1{,}43} \cdot \gamma = \frac{-0{,}038 - \bar{c_a} \cdot STM}{1{,}48 \cdot 10^{-5} \cdot (\alpha_g - 3{,}3^\circ)}$$

Abbreviating we set B = $\Lambda^{1.43}$ times $\gamma$.

Furthermore w eassume $c_a$-overline = 0.6 and STM = 0.05 (lower limit).

Then, we get

$$B = \frac{-0{,}038 - 0{,}6 \cdot 0{,}05}{1{,}48 \cdot 10^{-5} \cdot (\alpha_g - 3{,}3°)} = \frac{-4595}{\alpha_g - 3{,}3°}$$

For $\alpha_g$ = -2, -4, -6, -8, - 10 degrees we get

| $\alpha_g°$ | -2 | -4 | -6 | -8 | -10 |
|---|---|---|---|---|---|
| $B$ | 867 | 629 | 494 | 407 | 345 |

From the value B that is given for each $\alpha_g$ we now can calculate the sweep $\gamma$ if $\Lambda$ is given or can calculate $\Lambda$ if $\gamma$ is given:

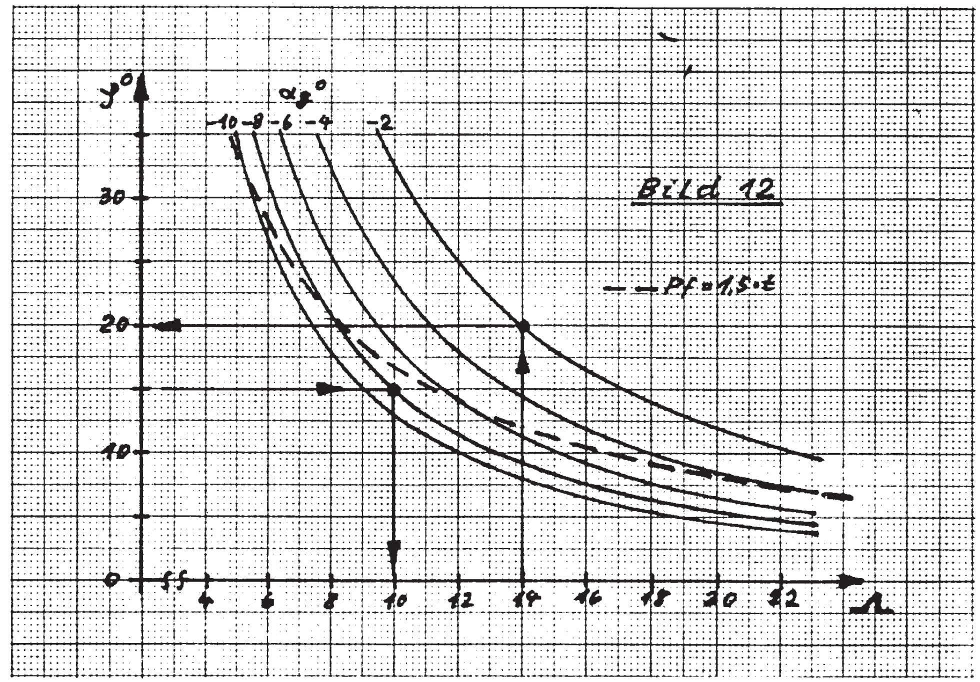
$$\varphi = \frac{B}{\Lambda^{1{,}43}} \quad \text{or} \quad \Lambda = \left(\frac{B}{\varphi}\right)^{0{,}699}$$

In the following table the calculated required sweep angle is given dependent on the chosen aspect ratio. In Picture 12 the results are given in a diagram.

Required sweep angle $\gamma$:

| $\Lambda$ \ $\alpha_g°$ | -2 | -4 | -6 | -8 | -10 |
|---|---|---|---|---|---|
| 4 | 119 | 87 | 68 | 56 | 48 |
| 8 | 44 | 32 | 25 | 21 | 17.6 |
| 12 | 25 | 18 | 14.1 | 11.6 | 9.9 |
| 16 | 16.4 | 11.9 | 9.4 | 7.7 | 6.6 |
| 20 | 11.9 | 8.7 | 6.8 | 5.6 | 4.8 |

<Picture 12>




Picture 12

From the diagram an aspect ratio and a sweep angle can be given for every twist angle.

For instance:

twist $\alpha_g$ = -2 degrees, a.r. $\Lambda$ = 14, sweep $\gamma$ = 20 degrees,
twist $\alpha_g$ = -8 degrees, sweep $\gamma$ = 15 degrees, a.r. $\Lambda$ = 10.

Let's look once more at the Picture from [ 5 ]. The length of the span is free, but between sweep angle and aspect ratio there is a constant relation: The sweep measure is constant and equal to 1.5 · t.

Written in a formula, we have

$$1{,}5 \cdot t = \frac{b}{2} \cdot tg\,\varphi = 9{,}1 \cdot 10^{-3} \cdot b \cdot \varphi \quad \text{or} \quad \varphi = 165 \frac{1}{\Lambda}$$

If we insert this into our formula for B, we get

$$B = \Lambda^{1,43} \cdot \frac{165}{\Lambda} = 165 \cdot \Lambda^{0,43}$$

For each $\alpha_g$ we now have only one pair of values for $\Lambda$ and phi for which the moment equation is fulfilled. For each $\alpha_g$ or B we get the corresponding $\Lambda$ and phi from

$$\Lambda = \left(\frac{B}{165}\right)^{2,33} \quad \text{and} \quad \varphi = \frac{165}{\Lambda}$$

In the following table the values of $\Lambda$ and phi corresponding to $\alpha_g$ = -2, -4 degrees and so on are given; these values are also plotted as dotted line in Picture 12.

| $\alpha_g^\circ$ | -2 | -4 | -6 | -8 | -10 |
|---|---|---|---|---|---|
| $\Lambda$ | 47 | 22.5 | 12.8 | 8.2 | 5.6 |
| $\varphi^\circ$ | 3.5 | 7.3 | 12.9 | 20 | 29.5 |

Now we see that if a constant "sweep measure" of 1.5 · t and a geometric twist of -2 degrees are given, we get a non practicable $\Lambda$ of 47 and only 3.5 degrees sweep. Just with a twist of 4 degrees we still get the very large aspect ratio of 22.5. So the sweep measure of 1.5 · t is not applicable.

Just if we do no more use this sweep measure, but do allow pairs of $\Lambda$ and $\gamma$ according to our calculations above, with $\alpha_g$ = -2 degrees we still get relative large values for $\Lambda$ and/or sweep. Beginning with $\alpha_g$ = -4 degrees $\Lambda$ and sweep come to regions where they are applicable without big problems. So, our theory confirms the experiences from the practice.

When using the diagram above we should consider that it was made with a STM of only 0.05, so a safety margin for $\Lambda$ or $\gamma$ is appropriate.

In the same way we could draw diagrams for tapered wings or for other airfoils. In those diagrams we have a useful tool for better understanding and for reliable design of swept trapezoid wings.

Conclusion

We have seen how the quantities which are essential in the design of a flying wing model (sweep, aspect ratio, twist and airfoil) interact, and how it is possible to calculate them for a swept linear twisted trapezoid wing.

In the same way other wing plan forms can be designed, too. But normally no "closed formulae" are possible, which would allow a simple and fast calculation. Then, every single design has to be calculated using this special data, what is feasible in a tolerable amount of time only by the aid of a computer.

For some time model builders have used microcomputer programs for this task. These are an excellent tool and contribute to augment our knowledge of "why" and "how." Not at last this leads to models with higher performance.

But besides the theoretical part also the practice should not go short. Each theory or design method needs the confirmation by practical application. So the author is grateful for any feedback from practice.

Besides this, we should always remember that no calculation result can be better than the data on which it is based. Unfortunately, there is a big gap just concerning the airfoil moment coefficients, which are very important herein. Who does calculations like these done here is dependent on values which are theoretical or are obtained with much higher Reynolds numbers. But this should not prevent anyone from a calculation, the results lead at least to the neighborhood of the true values, and the inclination to bigger models, i.e. to bigger Reynolds numbers, is helping there.

Literature:


[ 1 ] Schlichting-Truckenbrodt Aerodynamik des Flugzeugs: Bd. 1 und 2. Springer-Verlag.

[ 2 ] Kuechemann, D., A Simple Method for Calculating the Span and Chordwise Loading on Straight and Swept Wings of Any Given Aspect Ratio at Subsonic Speeds. R.A.E. Reports and Memoranda Nr. 2935, August 1952.

[ 3 ] Schlichting, H., Neure Beitraege der Forschung zur aerodynamischen Fluegelgestaltung. Jahr der deutschen Luftfahrtforschung 1940; S. I 113 ff.

[ 4 ] Thies, W., Pfeilung - ja - aber wie gross? Flug- und Modelltechnik Nr. 2/84: S. 150 ff.

[ 5 ] Thies, W., EPPLER-PROFILE. Fachschreiftenreihe modell-technik-berater. Verlag fuer Technik und Handwerk, Baden-Baden, 1974.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This paper by Helmut Schenk was the impetus behind Dr. Walter Panknin's Flying Rainbow project as presented at the 1989 MARCS Symposium. For more information on Dr. Panknin's research and models, please see <http://www.b2streamlines.com/Panknin.html> and see the appropriate On the 'Wing... columns as indexed at and available through <http://www.b2streamlines.com/OTW.html>.

# Maple Leaf Design Presents

# Royale

Don Peters, don@mapleleafdesign.com
Skip Miller Models <http://www.skipmillermodels.com>

Jeffery Thomas Sanford posted the Maple Leaf Design Royale an his RC Soaring and Sailplane Society FaceBook page <https://www.facebook.com/groups/RCSoaringAndSailplaneSociety/> a couple of days ago. (Photos from Jeffery's FB page - no snow visible - are included on the next two pages.)

The various comments that came in included this from Daryl Perkins...

"I only had a few flights on the Royale. Mine was the first plane out of the tools. I was mostly testing the spar stiffness and strength. In other words, I was trying to break it. Didn't have much wind, so no conditions to break it in, but I was able to stall the B winch. Spar looks solid. I was mostly impressed with its sink rate, AND ability to cover ground. This plane will work quite well in the wind lightly loaded.

"First flights were quite impressive. A very... VERY fine sailplane!"

For the curious, we've included a table showing a comparison between the Icon2 and the new Royale.

The line is already forming and the list started. Call Don at Maple Leaf Design <http://www.mapleleafdesign.com> or Skip Miller Models <http://www.skipmillermodels.com> to reserve yours.

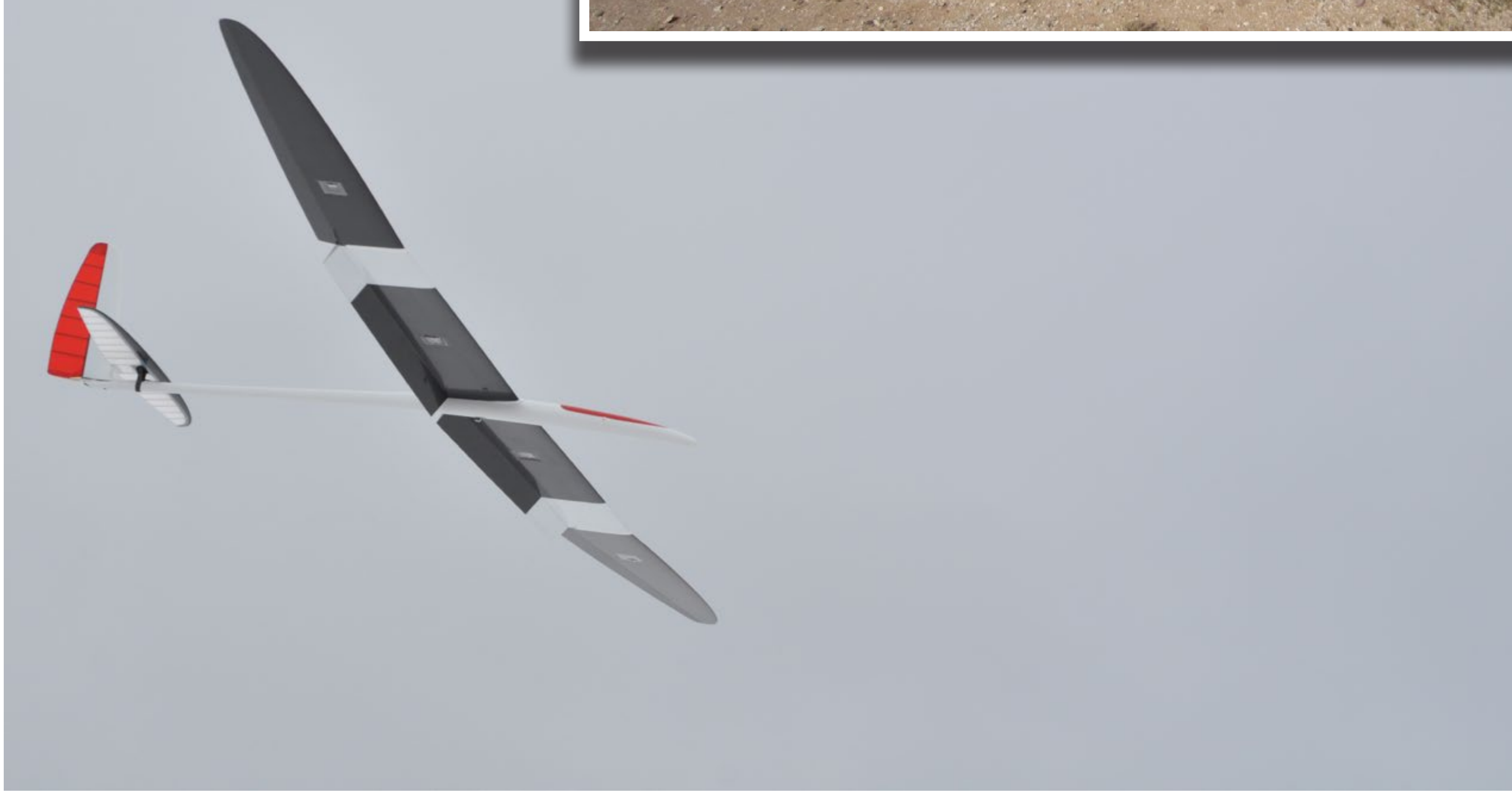
### Icon2 / Royale Comparison

| | Royale | Icon 2 |
|---|---|---|
| Span | 4 meters, 158" | 3.81 meters, 150" |
| Wing Area | 1400 $in^2$ | 1260 $in^2$ |
| Aspect Ratio | 17.83 | 17.85 |
| Weight | 56 - 72 ounces | 67 - 73 ounces |
| Wing Loading | 5.9 to 7.4 $oz/ft^2$ | 7.7 to 8.3 $oz/ft^2$ |


*Left: Cody Remington hooks up the Royale for another launch.*

*Right: Skip Miller and the new Royale.*

*Ignore the "i4" moniker stenciled on the wing; this is the Royale.*
*Opposite: Note the large flaps, here deflected about 80 degrees.*

Review

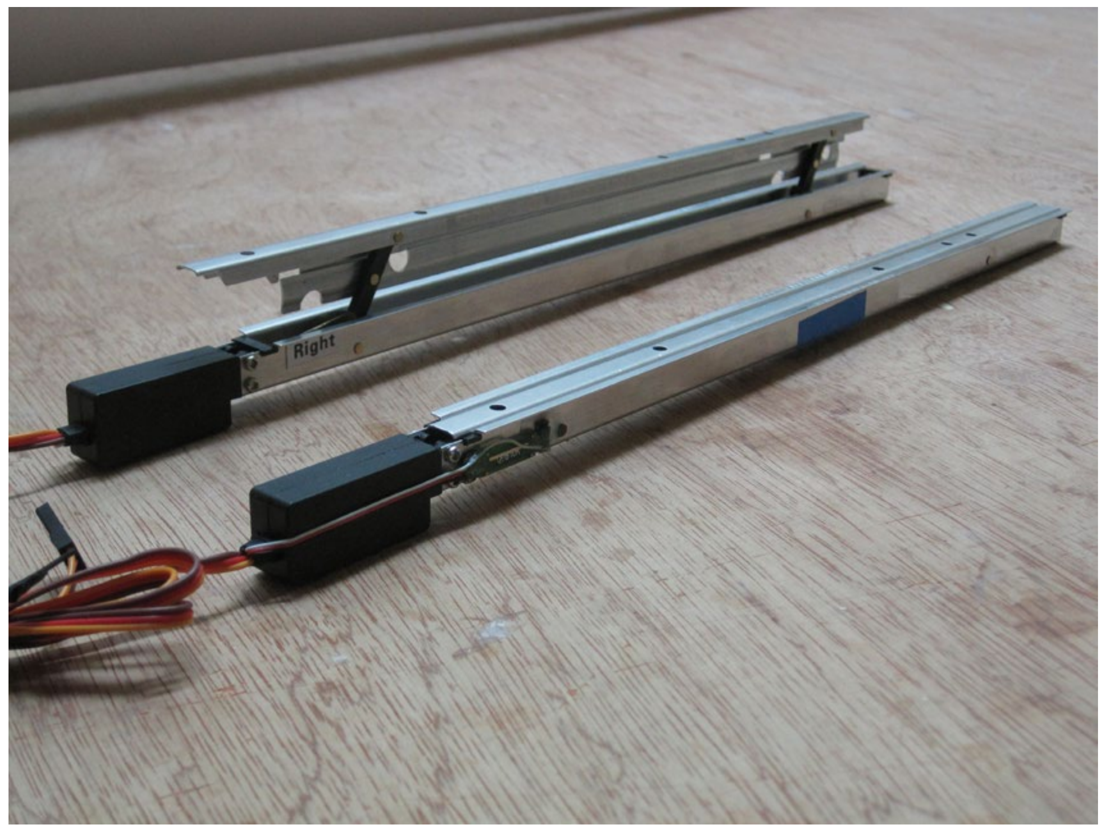
# HobbyKing Servoless Spoilers

Chris Evans, <http://www.scipie.com>

Sailplanes glide really well. That's what they're all about after all, floating around up there without a care in the world. That's fine until you decide to land the darn-thing and instead it just keeps floating along, clear over the end of the field and continues well into the next county. Enter the spoiler. At the flick of a switch these gravity-enhancing gizmos turn an otherwise clean airframe into something more akin to a brick. By feeding in variable amounts of "brickness" you can thus set her down within the same zip code. Wonderful!

RC spoilers have been around for donkey's years but they're generally a bit of a pain to install. Carve a big slot in the wing and drop in a set. Hack-out a few more chunks for the servos then fiddle around with pesky linkages all inside a space that'd crowd a mite.

Why doesn't someone combine a spoiler, a servo and the linkage into one complete unit? Wouldn't that be nice?



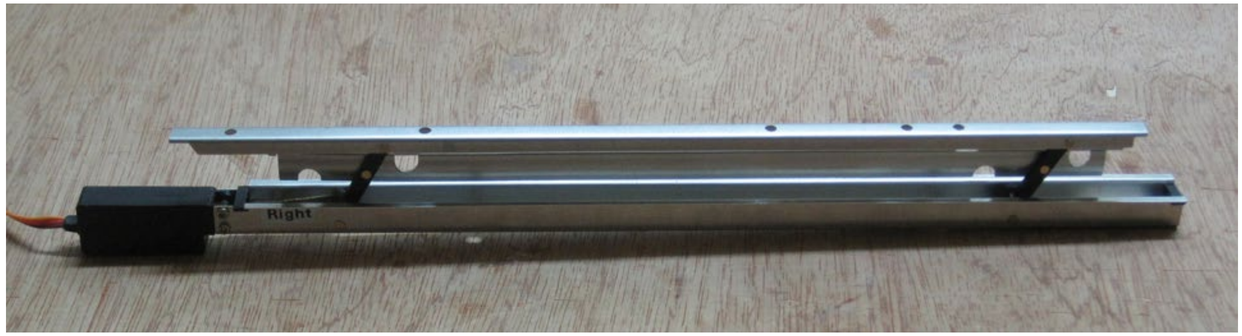
HobbyKing isn't the first to offer servoless spoilers, but I'm pretty sure they're the first to offer an economy set geared towards the casual Sunday park-flyer type. These are not high-end, stick 'em in your $7000 scale composite ship sorta blades. However, if you've ever thought it'd be neat to have spoilers in your foamie Easy-Glider or two meter glass slipper, these might be the ticket.

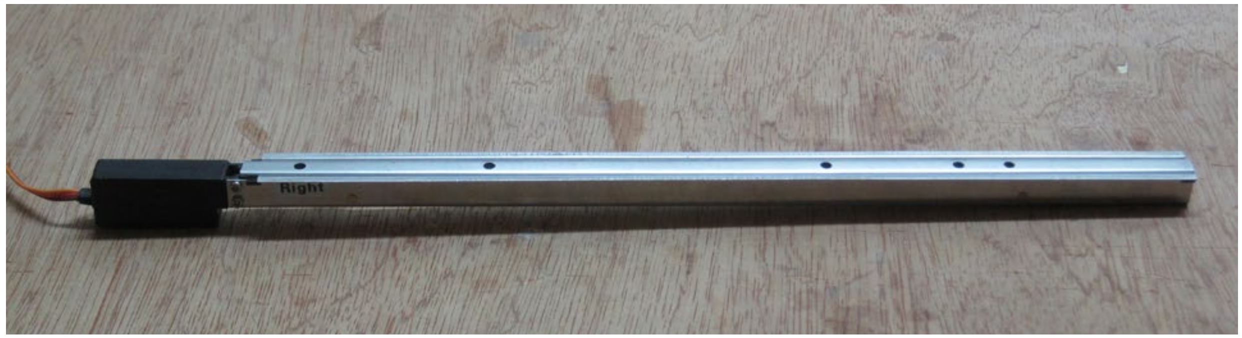
<http://www.hobbyking.com/hobbyking/store/__28455__Glider_Spoiler_Servoless_Left_and_Right_Pair.html>

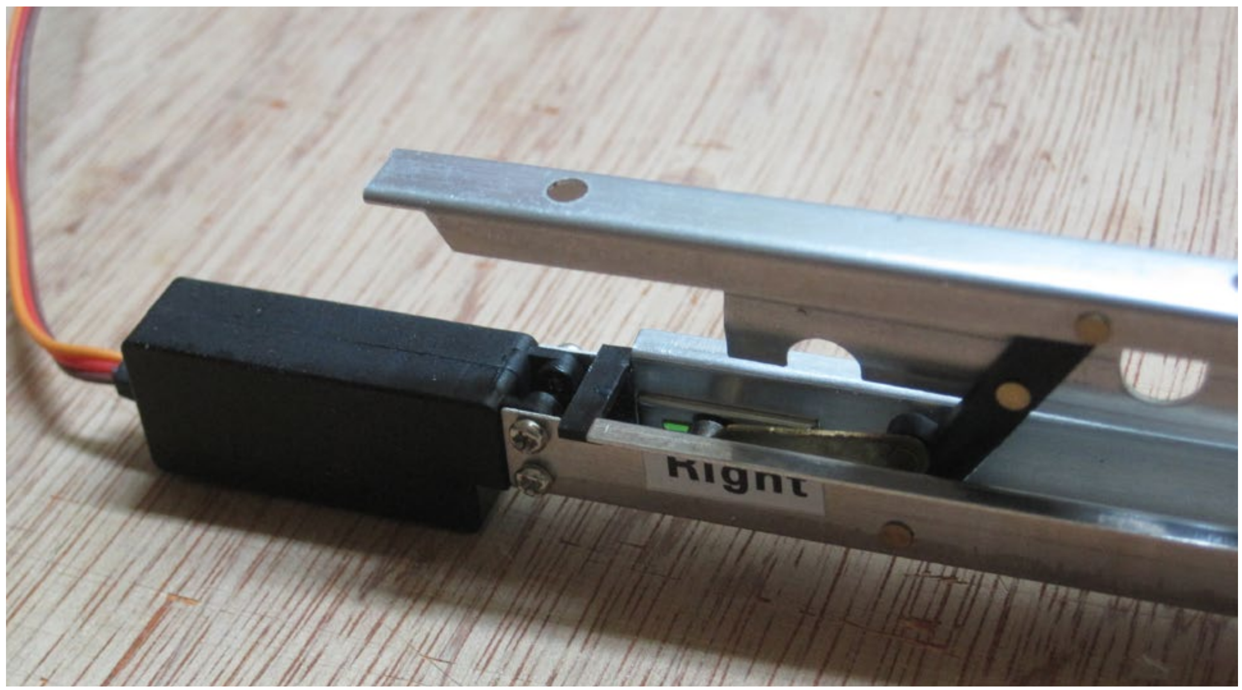
Specifications:
Voltage: 5-6v
Overall length: 300mm
Blade length: 255mm
Installation Depth: 10mm
Height Deployed: 20mm
Plug: JR Style
Weight: 40g each

They come in left and right units, either sold separately or as a combo. My pair arrived well packaged which was annoying as I wanted to plug them in right away and try them out. After a short battle with the bubble-wrap I had them hooked-up via a Y-harness to my receiver's throttle channel.

Before powering them up I centered the stick and adjusted the end throws down to around 30%. I've heard horror stories about other brands of e-spoilers burning out their motors if pushed beyond their travel limits. Hooked up the LiPo and ta-dah, they sprang to life. Kewl!



Well only fifty percent kewl. The right spoiler deployed nicely, moved in perfect unison with my control inputs. The left spoiler, however, had other ideas. It whined defiantly then flung itself open-n-closed as if flipping me the bird. I'll admit this is not the first defective/rude product HobbyKing has sent my way. At these prices however, I find myself a little more tolerant of the occasional flaky, wayward part.

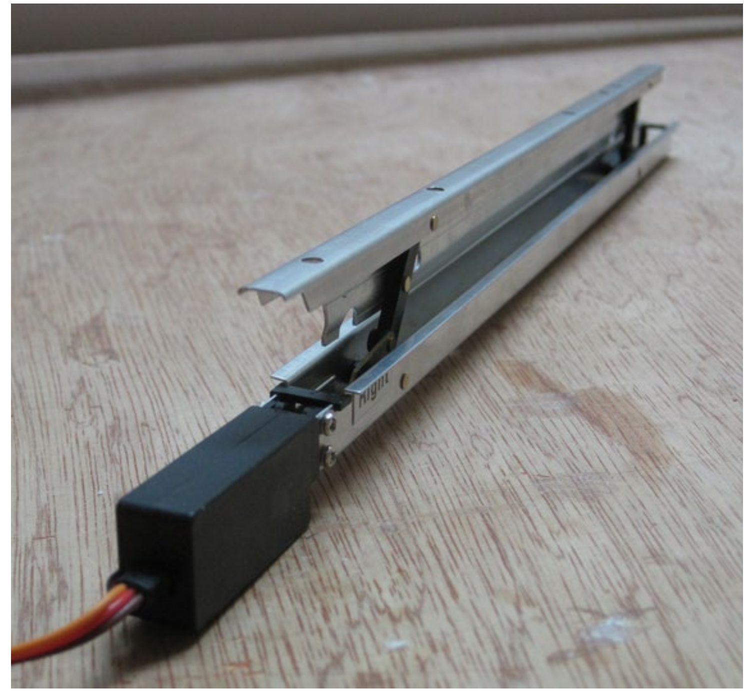
So after some futzing around to see if there was any hope for Mr. Right spoiler's evil twin I concluded it was officially FUBAR and I turned my attention instead to the good son. The action is pretty fluid although it sounds a little raspy. I dialled in more travel and explored the blade's full range of motion.

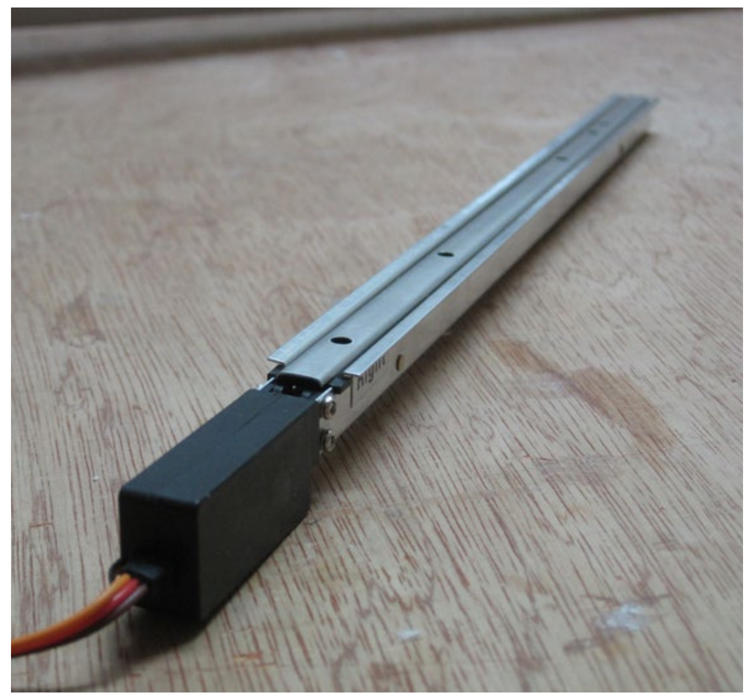
Interestingly, while doing so I discovered the motor simply shuts down once the blade fully extends. You can't bottom these out or run past the endpoint. The same applies when she's retracted. So basically these are idiot proof, you can't smoke the motor by setting up too much travel. That's a very nice feature, something I wish other e-spoiler manufacturers would adopt.

Next I looked at exactly how much of the throttle channel the spoiler could use. For whatever reason, these guys only use a small portion of the channel's travel, somewhere between a quarter and a half. While this isn't a big deal, it does mean once you've programmed your end points, you're not left with a whole lot of resolution. Then again do you even need all that much? It's not like this is a super critical control surface like an elevator or aileron. She's smooth enough for a spoiler.

Here's where we start to see a bit of a quality issue. When deployed the blade displays a fair amount of movement with some slop evident in the linkage. I expect these would rattle around in the wind a tad. Thankfully however, once retracted, the blade is held firmly in place. A common issue with spoilers of all types is the tendency for the low pressure region above the wing's airfoil to suck the blade up out of the wing slightly. These look like they'd do an adequate job of holding things in place.

I have no idea how much torque these can handle but on the bench at least, the blade moves with authority and is quite fast. I placed my hand on top to get a feel for how strong these are and they felt plenty good. I wouldn't sit on them but the motor has enough oomph to do the job and then some.





So with only one functioning spoiler I've not had an opportunity to test these in an airframe. I can't comment on issues like durability or effectiveness in the field. Note this review is purely a first impression/ bench test.

So what do we think of our bargain HobbyKing servoless spoilers-o-doom? Well, based on my initial impression, feel and functionality on the bench, I'd give these a 3 out of 5.

Pros:
- Easy installation, no servos, no linkages
- Fairly smooth proportional action
- Price - they're dirt-cheap ($30/pair)

Cons:
- Somewhat low resolution, could be smoother
- Slop in linkages - blade rattles when deployed

I'd be quite happy installing these in a Radian or an Easy Glider. I may install a set in my 100" Discus. Would I put these in my four meter sailplanes? Probably not. I think these are an attractive offering for low to medium-end/small to midsized applications. We'll have to see how they perform in the air though. Give em a try, see what you think.

A YouTube video version of this review can be found here: <http://youtu.be/fvAWumbBI4U>

(Editor's note: In looking at other posts on various internet sites, it seems as though the left unit is more likely to be problematic than the right. HobbyKing, to their credit, has so far been very good at replacing defective units according to what we've read.)

# building the Hitec sailplane

Pete Carr WW3O, wb3bqo@yahoo.com

*The Hitec is assembled and checked for the various alignments. At the same time the two servos for rudder and elevator are installed to be sure the pushrods from the tail would line up with both servo arms.*

This isn't a step by step discussion of how to build this aircraft. Rather, it illustrates how things can start simple, then continue until they get way out of hand.

Case in point.

A Yahoo user group where I subscribe indicated that a member was relocating and had several Ace radios to sell. I love those old rigs so emailed the gentleman and bought his inventory.

One rig was a MicroPro 8000 in excellent condition. I replaced the battery and powered it up to find that it had the original EPROM installed in the encoder.

Dan WB4GUK of Paris Kentucky offers an upgraded chip with modern features that is an easy swap for the old one. I sent for one and also installed a 53.3 MHz RF deck to put the radio in the Ham band.

I had a Silver Seven AM receiver on hand so modified the channels 2 and 7 outputs for 4046 IC chips that act as noise traps.

*This is the outer wing panel of the Hitec. Wiring and a 3-pin Deans plug are connected to the servo. The inboard rib bay is covered in 1/16th balsa and excess wiring can be pushed into the resulting cavity when the entire wing is assembled.*

*HS-82 MG servos are used on the ailerons. The setup of the servo arm was to give differential throw with much more up than down deflection. The servo is securely mounted to the top sheeting.*

This gave me control of separate aileron servos.

Now I had a radio with modern mixing and needed something to put it in.

A couple years ago I had built a hand launched sailplane with glassed sheet tail feathers. Before that I'd always used built up stabs and rudders believing that they gave smoother and more precise control.

That HLG proved an eye opener as it was an excellent performer. Of note was the increased effectiveness of the rudder which I believed came from the very low cross sectional area of the tubular rear fuselage.

At about the same time, a flying buddy, Rich Skellen, had purchased a 1.5 meter span ARF sailplane that used the ailerons as speed brakes with transmitter mixing. This was sort of like half CROW. The idea of having one control do the work of two was intriguing. When the design for the Hitec was first applied to paper this feature was included.

*Far left: This is the forward section of the fuselage with the nose at left. Bulkheads for the front edge of the wing and also the two at the rear for the carbon boom are installed. Some extra time was spent shaping the hole in the forward boom mount bulkhead so that it would be dead straight with the fuselage and also zero degrees with respect to the wing angle.*

*Left: In this view we are looking from the rear of the fuselage toward the nose. The wing has a 3/8 inch dowel pin at the leading edge that plugs into an alignment hole in the arched bulkhead. A ¼ x 20 blind nut is mounted to a piece of 3/8 inch thick chunk of plywood and mounted in the fuselage. Epoxy holds the blind nut assembly in the correct position.*

I wanted a span of 114 inches with a six foot inner wing panel and plug-in type tips. The idea was to leave the inner wing section as clean and free of hinge lines as possible. I also wanted a bolt-on wing which experience has shown is lighter than using wing joiner rods at the center.

The fuselage is just a scaled up version of the HLG with enough room for the radio, servos and some ballast.

*Above: The fuselage has the canopy shaped and mounted as well as the carbon boom. The wing hold-down assembly is in it's final position and glued in. This is most easily done before the fuselage bottom sheeting is installed.*

*Right: The carbon tail boom is ½ inch O.D. and has no taper. It is 36 inches long and left full length during construction. I sight down the tube looking toward the nose and align it in the two rear bulkheads. The rear one is fairly snug while I make adjustments at the forward bulkhead only.*

Wing chord is eight inches to the poly break and then tapers to five inches at the tips. An MH-32 airfoil, lightly modified, was used.

I used three degrees of dihedral at the center and three more at each tip.

1/16th inch sheeting extends back to the spar which is level with the rib tops for maximum spar separation and strength.

The trailing edge is 1/16th sheeting and no cap strips were used. The area at the wing tip rod and tube was sheeted since

*The rudder and vertical fin are covered with light fiberglass cloth. Once cured I cut the two pieces apart so that they are absolutely straight. I then use a Dremel tool and sanding drum to make the lightening holes perfectly round.*

*The horizontal stab and elevator are built the same way as the rudder and vertical fin. Once the epoxy is cured I trim the excess cloth and cut the elevator loose.*

I like to tape the joints and don't want to pull the Monocote. In addition, I sheeted the area of the tip where the aileron servo would be mounted. This gave a secure support for the servo and also helps stiffen the tip against flutter.

Free flight model people use the phrase "add lightness." Throughout the build of the Hitec I used that phrase and came away with a 40 ounce sailplane ready to winch. In addition, I mounted the servos as high in the fuselage under the wing as possible. This was to clear the wing bolt/nut mount and also to raise the center of mass in the fuselage. The small dihedral plus the low all up weight of the ship lets it read lift extremely well.

As expected, the rudder is very effective and had to be reduced in throw to keep the ship from skidding in the turns. I'd also epoxied the stab to the tail boom instead of making it removable. While removable tails are handy for storage and transport the extra weight of the nuts and bolts that fasten it aren't worth the weight.

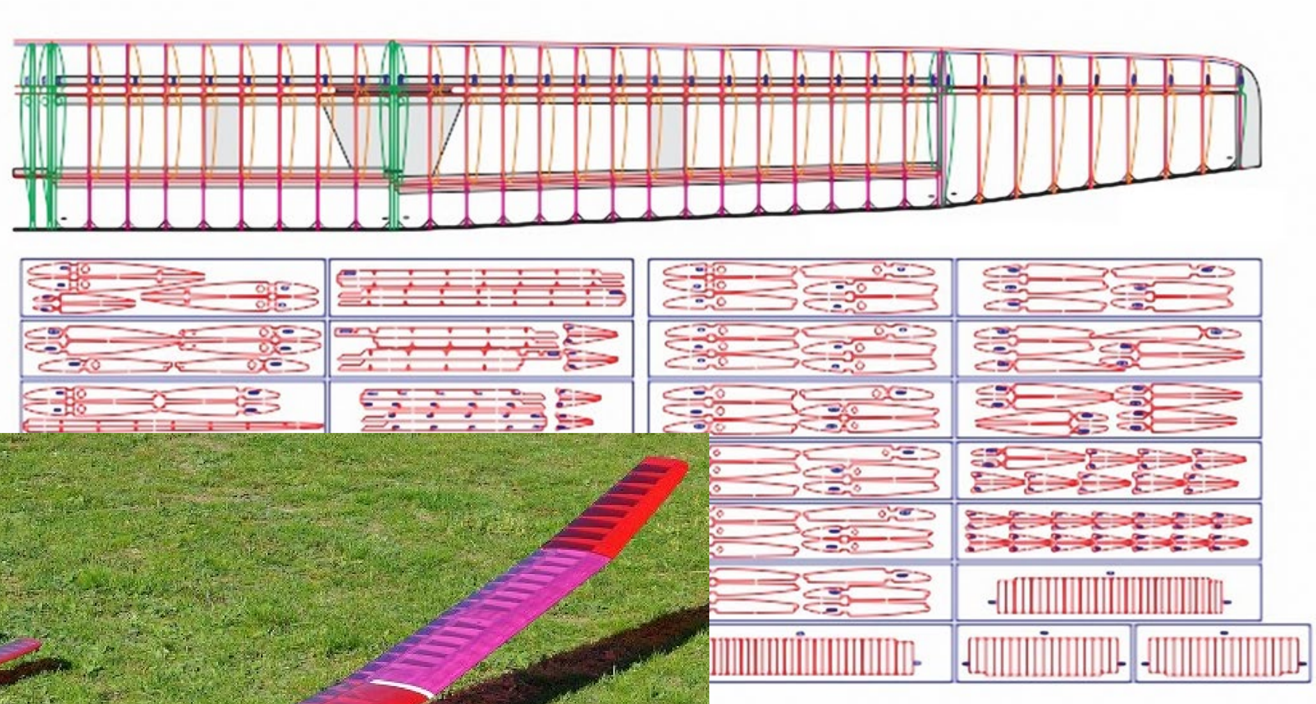
While the Hitec flies really well there are a sequence of interrelated adjustments that will be made.

- The CG was initially set to 30% of the wing chord but I feel it can come back a bit more. This means reducing the elevator throw and maybe adding expo to the control.
- The ballast location is just in front of wing bulkhead. There's room for about 12-14 ounces of lead sheet in several groups. I'll need to fly the ship at various weights and establish a set of trim changes for that.
- The new Level 7 chip in the transmitter will allow me to store entire aircraft setups, so I can select the proper model name and setup for each condition. Names that might be used are; Hitec breezy, Hitec windy or Hitec Holy Crap!

Anyway, the ship will be a blast to fly and I look forward to a summer of long thermal flights.

The Hitec, together with a lawn chair, cool drink and an iPod have the makings of a wonderful flying session.


*The ship was test flown at the Spring Soar-for-fun at Cumberland Maryland. The radio is a freshly reworked Ace MicroPro 8000 with the Level 7 EPROM chip installed. Center-of-gravity was initially set at 30% and could go further back. Also, the trims on the transmitter were set to have too much throw so needed to be backed off.*



# LATITUD 33

## *a laser-cut F5J machine*

Felipe Vadillo, felipevadillo@yahoo.com

Felipe Vadillo owns FMG Laser Works <http://www.fmglaser.com.ar> in Argentina. FMG Laser Works uses a pantograph VersaLaser to convert images or pictures from computer screen into real objects made with an amazing variety of materials (wood, plastic, cloth, paper, glass, leather, stone, ceramic, rubber, etc.). The applications of this technology are nearly limitless, from the production of architectural models to wedding souvenirs,

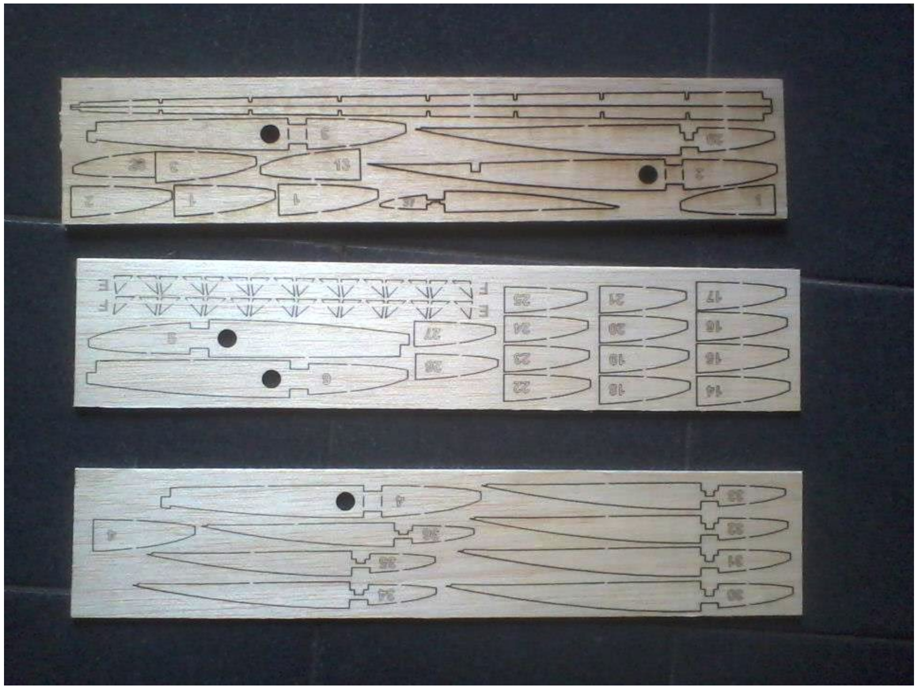
Of greatest interest to readers of *RCSD*, however, is the use of Felipe's machine to produce precision parts for RC sailplanes. Luckily, Felipe is an ardent participant in various RC soaring activities and has recently designed a large electric sailplane entirely suitable for F5J events, Latitud 33. <http://fmglaserkits.blogspot.com> The Latitud 33 wing and tail group are primarily of balsa. Plywood and extruded carbon parts are also incorporated for specific structural components where reinforcement or high strength and low weight are needed.

Felipe is not selling the Latitud 33 as an ARF or as a kit, but he is selling the cutting files. If you have a laser cutter and an interest or potential interest in the Latitud 33, please contact Felipe at <felipevadillo@yahoo.com> to obtain further information.

A video showing the step-by-step construction process can be viewed at <http://www.youtube.com/watch?v=6AFrDKoSW0Y>.

Video of the Latitud 33 in flight can be seen at <http://www.youtube.com/watch?v=nWPmi_w3KHs&feature=youtu.be>.

The following pages present a compilation of construction photos.



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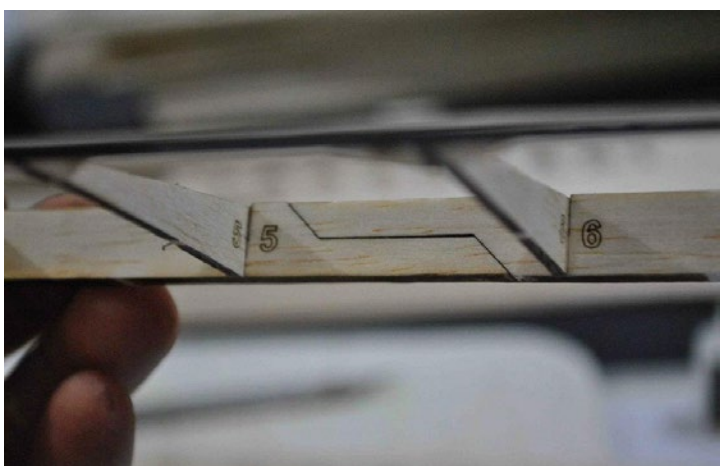
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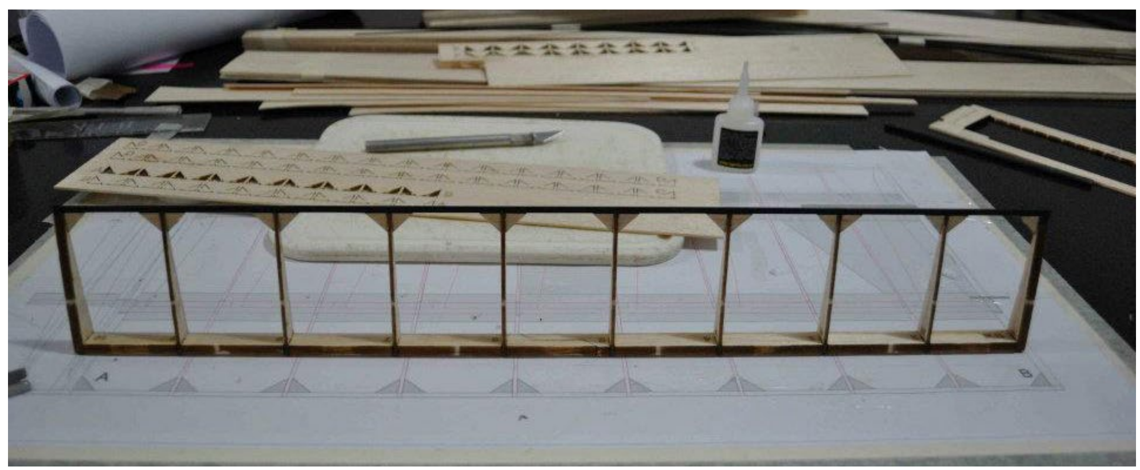


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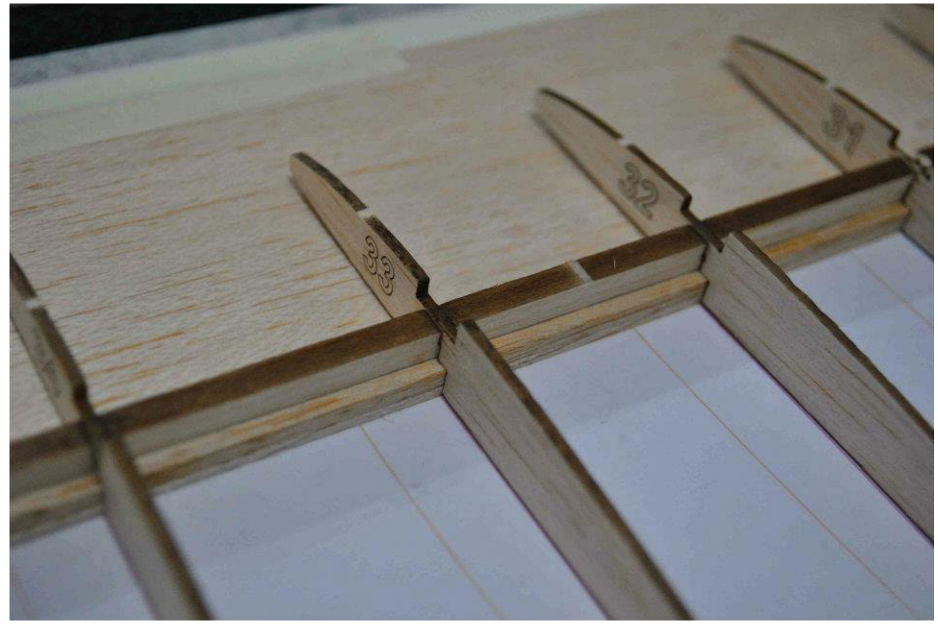
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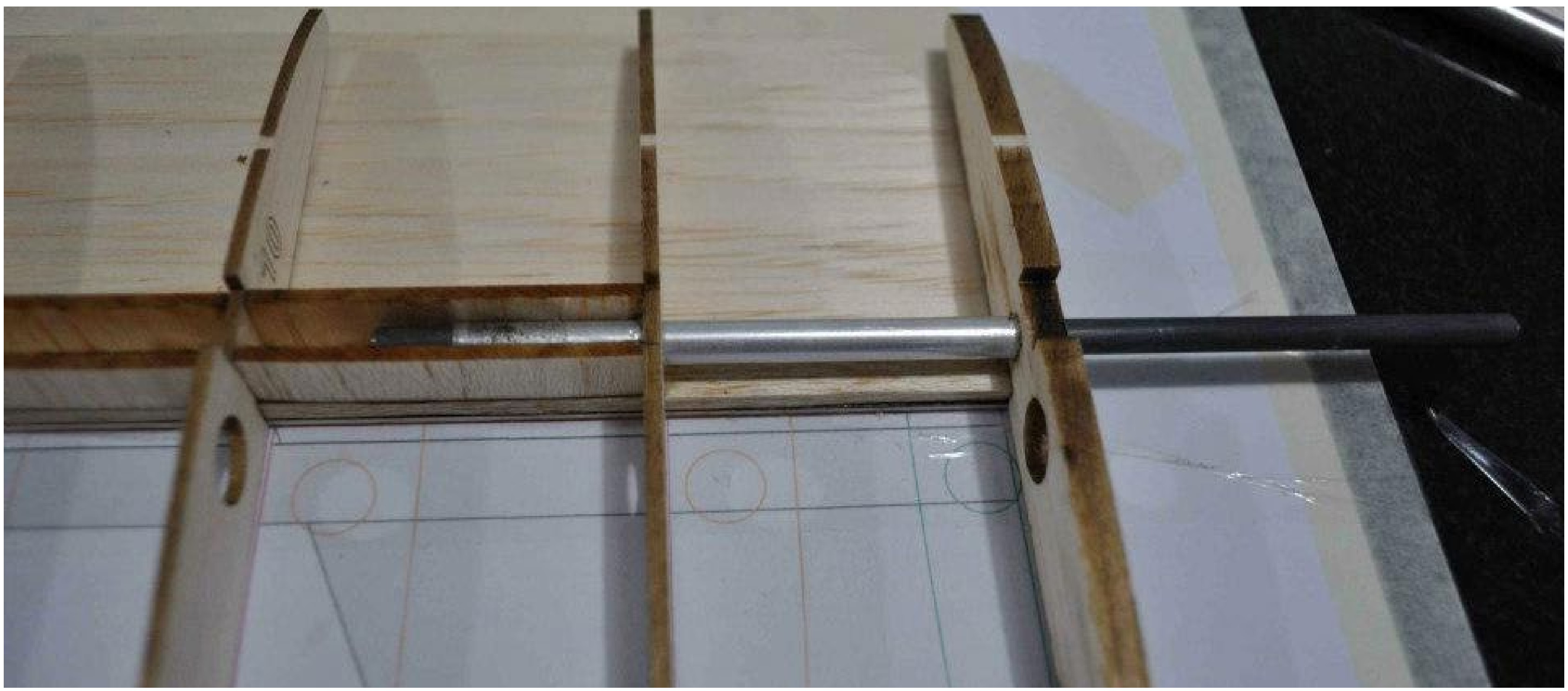


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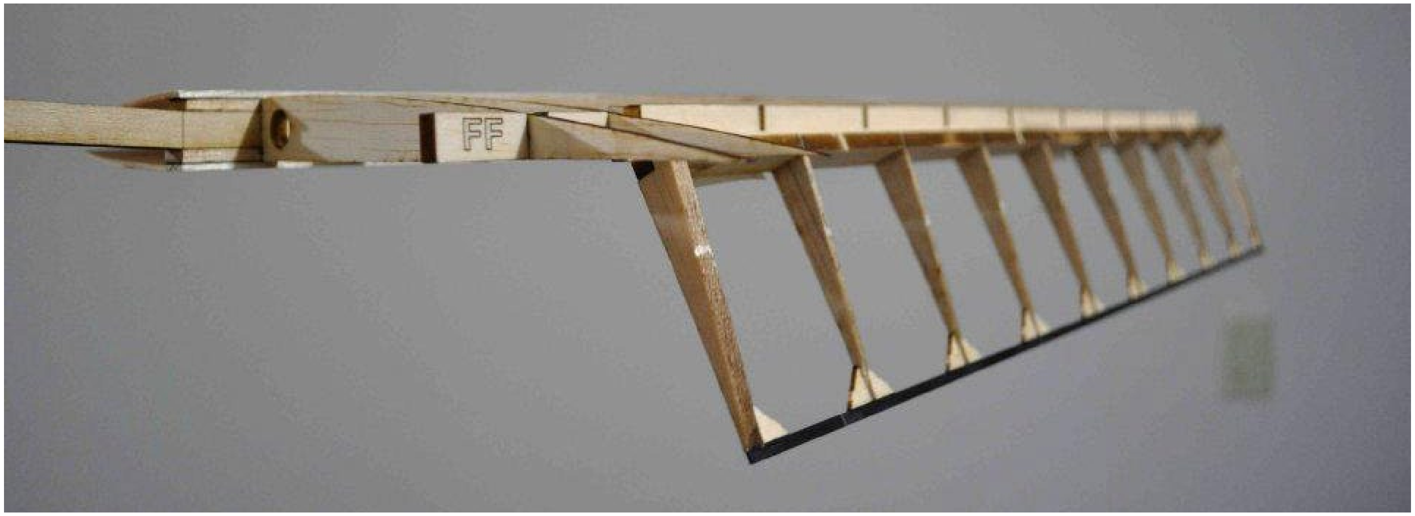
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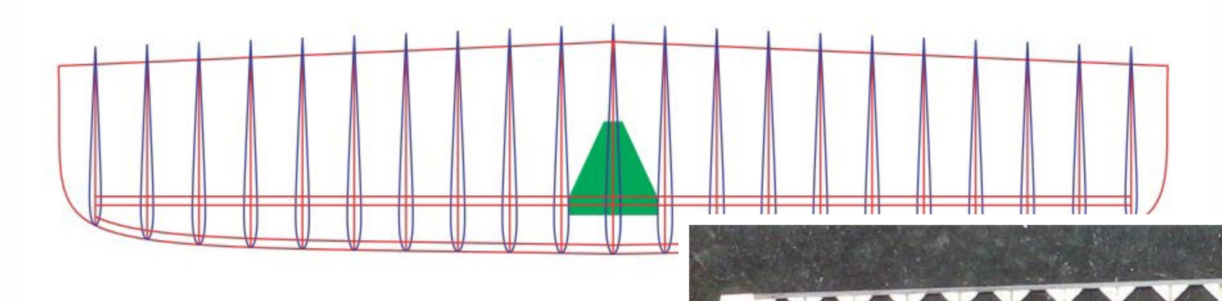

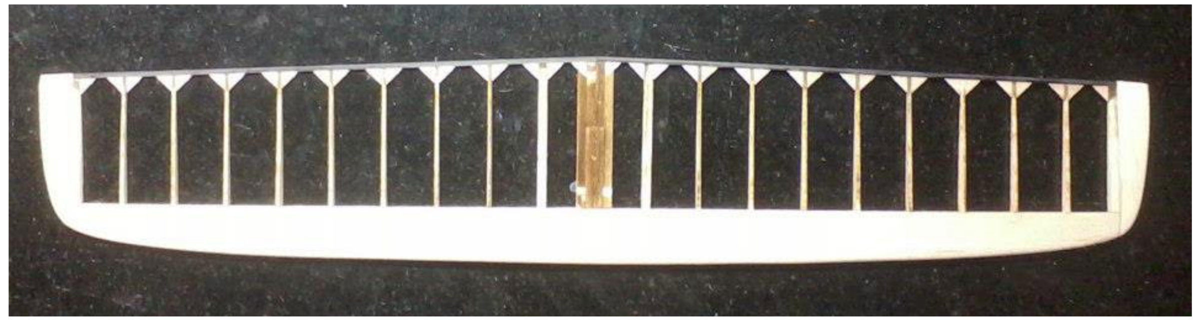

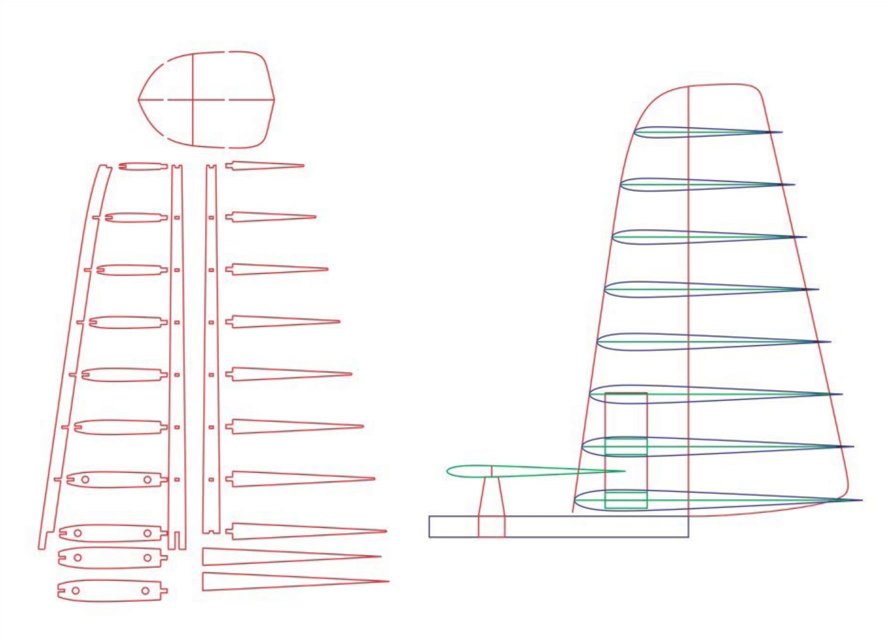

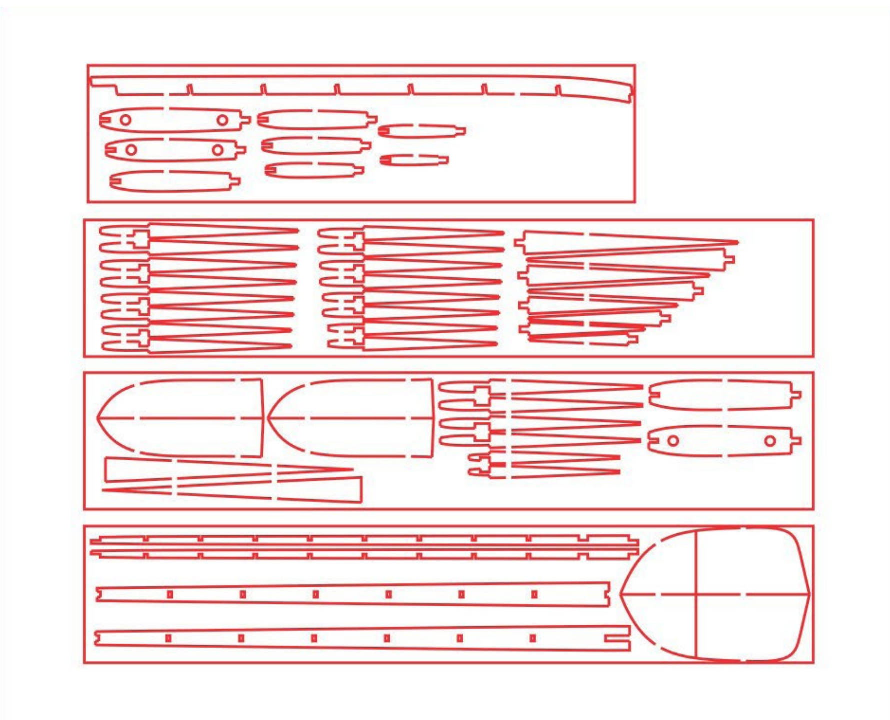

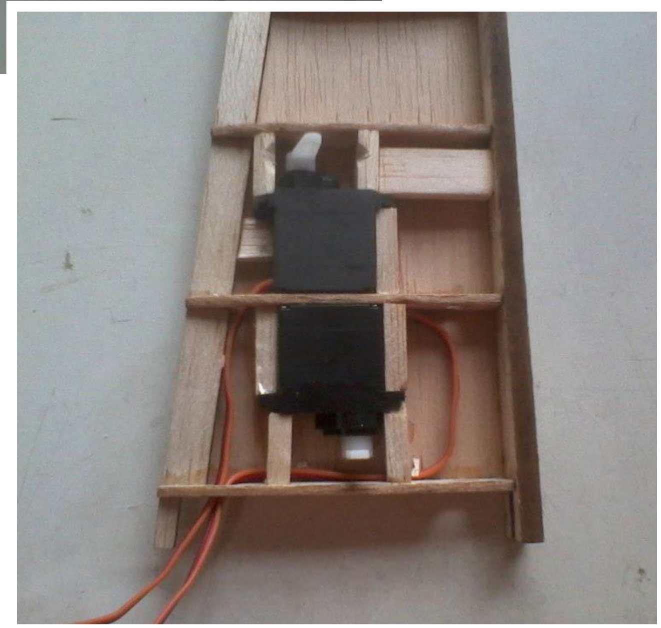




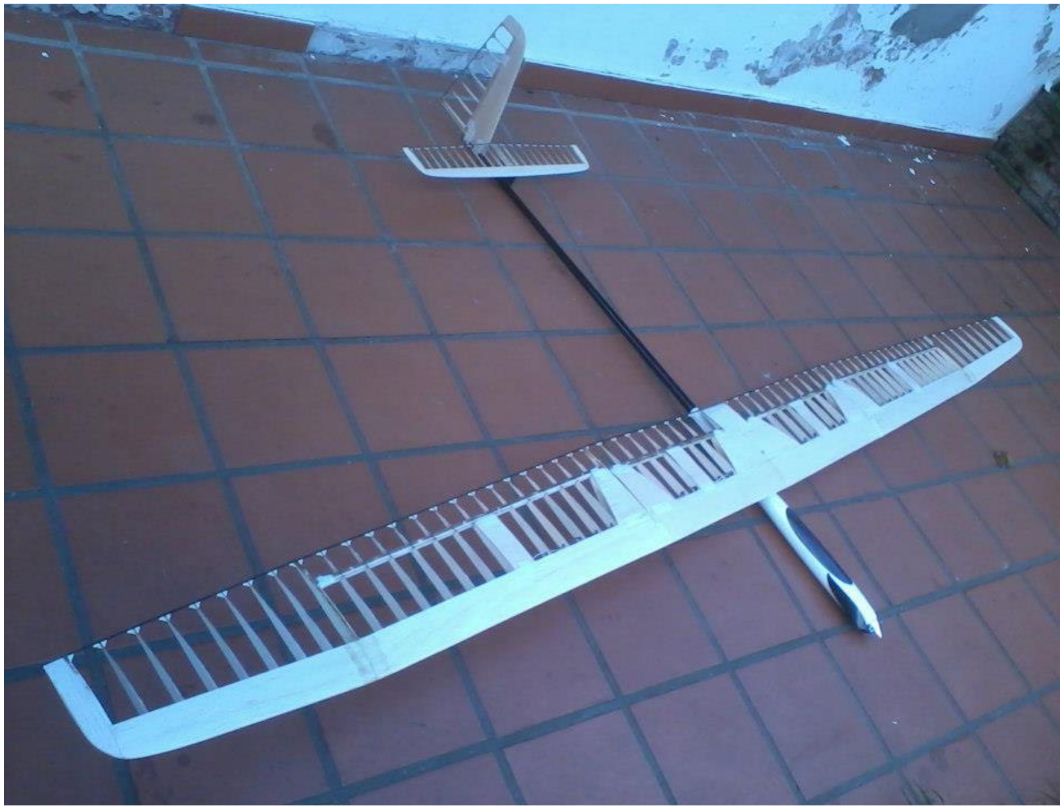

# NASA Researchers Work to Turn Blue Skies Green

Kathy Barnstorff, NASA Langley Research Center

02.27.13

A semi-span jet model is scheduled to be tested in NASA Langley's 14-by-22 Foot Subsonic Wind Tunnel this winter to evaluate aircraft noise reduction technologies as part of the Flap and Landing Gear Noise Reduction Flight Experiment.

Air travelers of the future could have quieter, greener and more fuel-efficient airliners because of NASA research efforts that are moving into further development and testing.

The Environmentally Responsible Aviation Project, which is part of the NASA Aeronautics Research Mission Directorate's Integrated Systems Research Program, was created in 2009 to explore aircraft concepts and technologies that will reduce the impact of aviation on the environment over the next 30 years.

During the first phase of ERA, engineers assessed dozens of broad areas of environmentally friendly aircraft technologies and then matured the most promising ones to the point that they can be tested together in a real world environment. Those experiments included nonstick coatings for low-drag wing designs, laboratory testing of a new composite manufacturing technique, advanced engine testing, and test flights of a remotely piloted hybrid wing body prototype.

"With the start of phase two, we will be able to take what we've learned and move from the laboratory to more flight and ground technology tests," said Fay Collier, ERA project manager based at NASA's Langley Research Center in Hampton, Va. "We have made a lot of progress in our research toward very quiet aircraft with low carbon footprints. But the real challenge is to integrate ideas and pieces together to make an even larger improvement. Our next steps will help us work towards that goal."

NASA has chosen eight, large-scale integrated technology demonstrations to advance ERA research. The demonstrations are designed to further the project's goals of simultaneous reduction in the amount of fuel used, the level of noise and the emissions produced by tomorrow's commercial transport planes.

Researchers will focus on five areas: aircraft drag reduction through innovative flow control concepts; weight reduction from advanced composite materials; fuel and noise reduction from advanced engines; emissions reductions from improved engine combustors; and fuel consumption and community noise reduction through innovative airframe and engine integration designs.

The integrated technology demonstrations, which build on work done during the first two years of NASA's ERA project, include:

1. Active Flow Control Enhanced Vertical Tail Flight Experiment: Tests of technology that can manipulate, on demand, the air that flows over a full-scale commercial aircraft tail.
2. Damage Arresting Composite Demonstration: Assessment of a low-weight, damage-tolerant, stitched composite structural concept, resulting in a 25

*A semi-span jet model is scheduled to be tested in NASA Langley's 14-by-22 Foot Subsonic Wind Tunnel this winter to evaluate aircraft noise reduction technologies as part of the Flap and Landing Gear Noise Reduction Flight Experiment. Image credit: NASA Langley/Sean Smith*

percent reduction in weight over state-of-the-art aircraft composite applications.

3. Adaptive Compliant Trailing Edge Flight Experiment: Demonstration of a non-rigid wing flap to establish its airworthiness in the flight environment.
4. Highly Loaded Front Block Compressor Demonstration: Tests to show Ultra High Bypass (UHB) or advanced turbofan efficiency improvements of a two-stage, transonic high-pressure engine compressor.
5. 2nd Generation UHB Ratio Propulsor Integration: Continued development of a geared turbofan engine to help reduce fuel consumption and noise.
6. Low Nitrogen Oxide Fuel Flexible Engine Combustor Integration: Demonstration of a full ring-shaped engine combustor that produces very low emissions.
7. Flap and Landing Gear Noise Reduction Flight Experiment: Analysis, wind tunnel and flight tests to design quieter flaps and landing gear without performance or weight penalties.
8. UHB Engine Integration for a Hybrid Wing Body: Verification of power plant and airframe integration concepts that will allow fuel consumption reductions in excess of 50 percent while reducing noise on the ground.

Key to ERA research is industry partnerships. Each of the demonstrations will include selected industry partners, many of which will contribute their own funding. "We are excited that ERA's research portfolio provides a healthy balance of industry and government partnerships working collaboratively to mature key technologies addressing ERA's aggressive fuel burn, noise and emission reductions goals for tomorrow's transport aircraft," said Ed Waggoner, Integrated Systems Research Program director.

The technology demonstrations are expected to begin next year and continue through 2015.

The ERA project is one of many NASA Aeronautics Research Mission Directorate programs and projects working to develop technologies to make aircraft safer, faster and more efficient, and to help transform the national air transportation system. That research is being conducted at NASA Langley, NASA's Ames Research Center at Moffett Field, Calif., NASA's Dryden Flight Research Center at Edwards Air Force Base, Calif., and NASA's Glenn Research Center in Cleveland.


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