R/C
Radio controlled
SOARING DIGEST
THE JOURNAL FOR R/C SOARING ENTHUSIASTS

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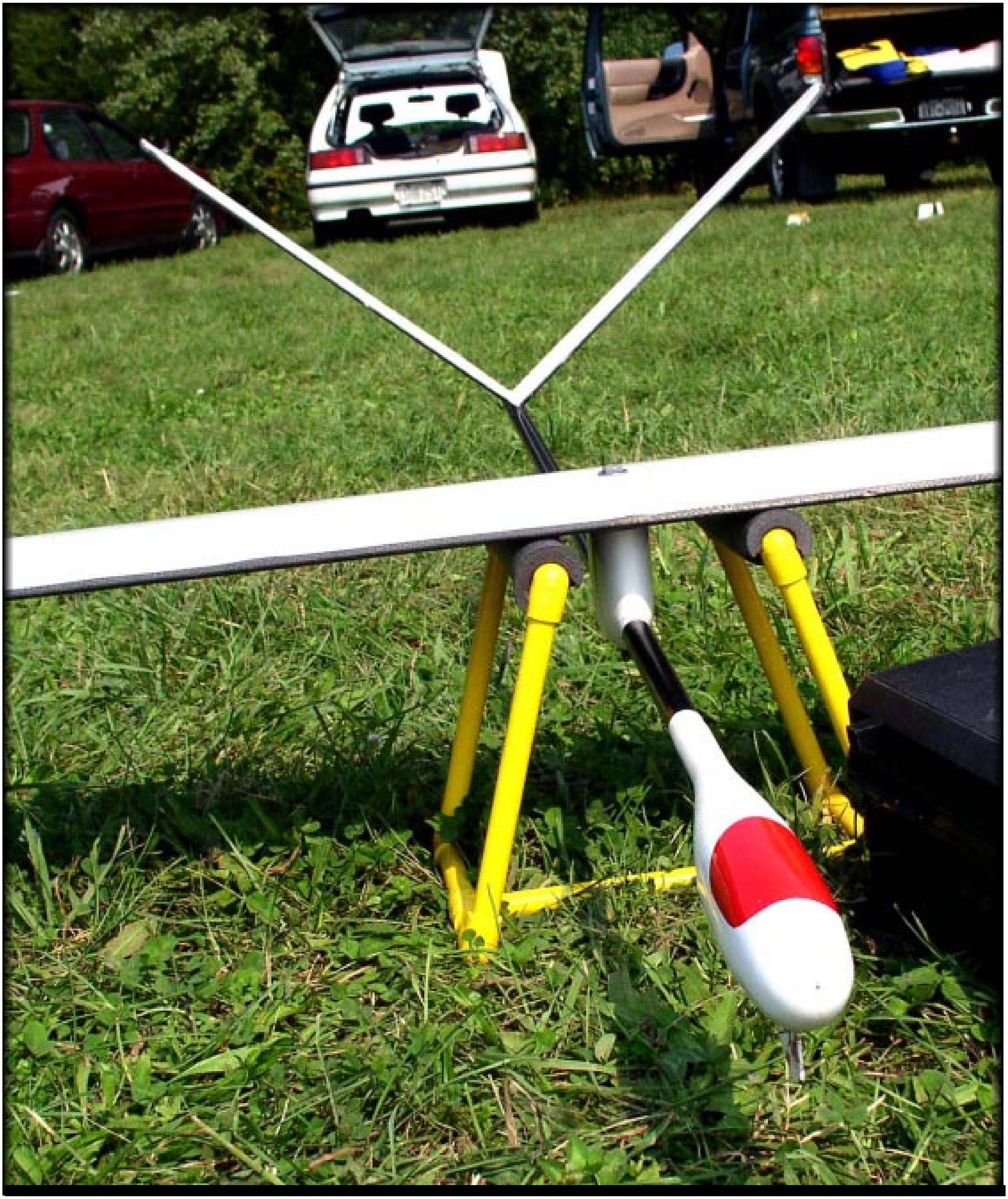

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ABOUT *RCSD*

R/C Soaring Digest (RCSD) is a reader-written monthly publication for the R/C sailplane enthusiast and has been published since January, 1984. It is dedicated to sharing technical and educational information. All material contributed must be exclusive and original and not infringe upon the copyrights of others. It is the policy of *RCSD* to provide accurate information. Please let us know of any error that significantly affects the meaning of a story. Because we encourage new ideas, the content of all articles, model designs, press & news releases, etc., are the opinion of the author and may not necessarily reflect those of *RCSD*. We encourage anyone who wishes to obtain additional information to contact the author. *RCSD* was founded by Jim Gray, lecturer and technical consultant.

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Don't forget to check out the *RCSD* web pages each month. Cover photographs are always available for viewing, and usually available for downloading, as well. Special article .pdf files are frequently available for a limited time, and of course our web masters update the highlights and status information of each issue as it becomes available.

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.... "The Square-Cube Law and Scaling for RC Sailplanes" by Dr. Michael Selig
.... "Modifying & Building the MB Raven (Parts 1-4)" by Bill & Bunny Kuhlman
.... "Butterfly and Moth Airbrushing Tutorial" by Joedy Drulia
Bookshelf Listings - A listing of recently published books of interest to aeromodelers.
Complete RCSD Index, 1984-2002

The Soaring Site

West Michigan Soaring Society

We received an e-mail from Cal Posthuma, President of the West Michigan Soaring Society (WMSS).

Cal says, "We have linked to your page from our NEW! site. I think you will like it. It is quite unique:

WWW.RCSOARING.ORG

"This is the home of the West Michigan Soaring Society out of Grand Rapids, Michigan. 29 members and growing fast."

So, we checked it out! And, for those of you that don't have computer access, Cal's phone number is 616-997-1905, cell 616-240-3972.

The purpose of WMSS, according to their web pages, and pretty much the same for most clubs follows:

1. To facilitate growth in the art of design, construction and flying of radio controlled soaring planes.
2. To serve fairly and in proper balance those people with interest in radio controlled soaring, whether their interests are thermal soaring, slope soaring, competition or sports flying for personal achievement.
3. To gather and disseminate information on glider design, construction and soaring techniques, kit evaluation, and launching techniques.
4. To promote safety in radio controlled soaring.
5. To promote annual soaring contests open to all members, of the soaring community and club meets in a manner that will consider the needs and desires of all the members.
6. To provide assistance to individuals interested in learning soaring.
7. To provide information on meets and notification of all members of soaring schedules.
8. To promote the advancement of member soaring skills through the attainment of League of Silent Flight (LSF) skill levels.

New Aeromodelling World Record Attempts (2) - 24.10.2003

B^2 sent in the following, with a note saying, "Maynard Hill et al crossing the Atlantic is now officially two world records!" Congrats, Maynard!

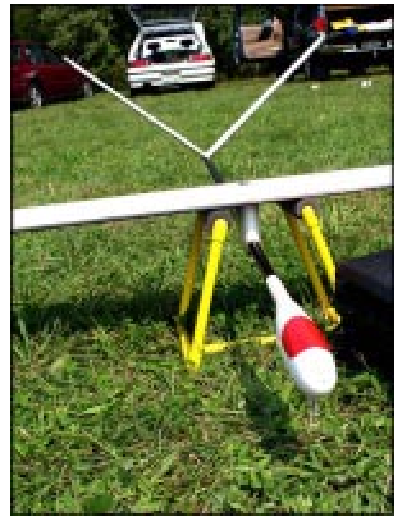
This is a message from the FAI 'Aeromodelling Information' mailing list.

CIAM Home Page:
http://www.fai.org/aeromodelling/

FAI has ratified the following Class F (Model Aircraft)records:

Claim number : 7882
Sub-class F3A (Aeroplane, piston motor)
F3: Radio controlled flight Category
Type of record : N°142: Distance in a straight line
Course/location : Cape Spear, NF (Canada) - Mannin Beach (Ireland)
Performance : 3030 km
Aeromodellers : Maynard L. HILL (USA), Barrett J. FOSTER, David G. BROWN
Date : 11.08.2003
Previous record : 832.43 km (14.06.1998 - Ronald C. CLEM, USA)

Claim number : 7883
Sub-class F3A (Aeroplane, piston motor)
F3: Radio controlled flight Category
Type of record : N°141: Duration
Course/location : Cape Spear, NF (Canada) - Mannin Beach (Ireland)
Performance : 38h 52 min 19 sec
Aeromodellers : Maynard L. HILL (USA), Barrett J. FOSTER, David G. BROWN
Date : 11.08.2003
Previous record : 33h 39mn 15s (01.10.1992 - Maynard L. HILL, USA)



Mantis

An absolutely gorgeous original Mantis from Phil Barnes owned by Bob Magee from Upstate New York. Details on the history of the Mantis, by Anker Berg-Sonne, will be included in the next issue of *RCSD*.

Photography courtesy of Anker Berg-Sonne.

Back Cover

Mantis

Anker's Luckenbach/Drela 130" Aegea Mantis.

Photography courtesy of Anker Berg-Sonne.

FAI congratulates the aeromodellers on their splendid achievements.

More information can be found here: http://records.fai.org/models/

Special Thanks

This month is no exception when it comes to saying thanks. By way of explanation, we recently received what turned out to be a series of articles from Mark Drela. (Thanks, Mark!) Quickly recognizing that a technical eye was needed to help format and ensure that all the material flowed and was accurately displayed, I turned to B^2 and yelled, "Help!"

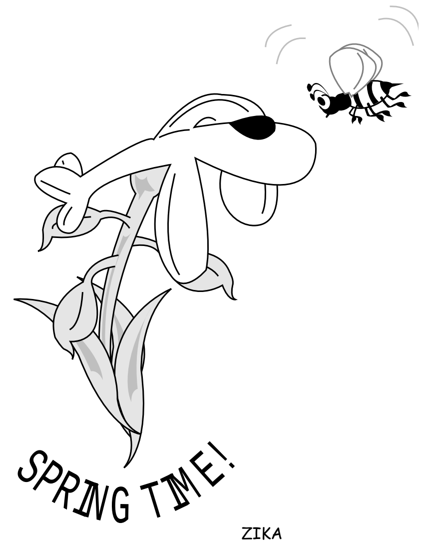
Needless to say, they're always there when I need them! And, from the bottom of my heart, I truly appreciate it! As well, that thanks also goes to Gordy Stahl and Paul Clark for their special support, letting other folks know about us this last month!

Happy Flying!
Judy Slates

SCHEDULE OF SPECIAL EVENTS

November 29-30, 2003
Tangerine Soaring Championships — Orlando, FL
www.orlandobuzzards.org

Please send in your scheduled 2004 events as they become available!



R/C Radio controlled Soaring Digest
THE JOURNAL FOR R/C SOARING ENTHUSIASTS
A MONTHLY LOOK INTO THE WORLD OF SAILPLANE ENTHUSIASTS EVERYWHERE

R/C Soaring Digest (RCSD) is a reader-written monthly publication for the R/C sailplane enthusiast. Published since 1984, *RCSD* is dedicated to the sharing of technical and educational information related to R/C soaring.

RCSD encourages new ideas, thereby creating a forum where modelers can exchange concepts and share findings, from theory to practical application. Article topics include design and construction of RC sailplanes, kit reviews, airfoil data, sources of hard to find items, and discussions of various flying techniques, to name just a few. Photos and illustrations are always in abundance.

There are *RCSD* subscribers worldwide.

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GORDY'S TRAVELS

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Nose Heavy Sailplanes are Easier to Fly???

I hear it continuously, heck it echoes through RC soaring time, and it's... true... sort of.

You get a new plane and the instructions suggest the "CG range" in so many inches usually measured from the leading edge. So you get out your 'balancing jig' put a mark under the wing and add lead till your model teeters approximately level. Fine, no problem with that because it's handy to have a starting point, where things get screwy and illogical is when you have created some elaborate balancing thing that suspends the model from a string, and has a laser level so that you can get it balanced right dead on that mark.

Ta Da! Your sailplane is 'balanced'...for sitting on a bench. Not for flying. Yes, guys, RC sailplanes are actually supposed to fly! RC sailplanes are dynamic, not static; they have to be balanced in the air, you know, while flying!

Gravity is always engaged; your elevators ONLY are empowered with airspeed.

Think that over. Twice. If your sailplane's nose has more lead than the wing needs to stay level, then the elevator (stabilizer) has to do extra work to keep the wing's leading edge from being pulled toward the ground. Gravity is always engaged. So when your sailplane's airspeed slows down, how can your elevator (stab) keep the nose from being pulled down?

Airspeed empowers your elevators (stabilizer). So, if your sailplane has more lead in its nose than is needed, then your elevators have to have up incidence in order to hold the nose from being pulled down by gravity. So, what happens when your sailplane's airspeed increases? Your sailplane's elevator gains power and the nose lead is overcome; the sailplane's nose is driven upwards. Then when the airspeed slows, the elevator loses its power and gravity grabs the nose again.

THIS is where that goofy dive test came about. "You push your sailplane's nose over and watch to see if your model pulls out in a gentle recovery."...Argh! At the point where the nose pulls out, your airspeed is at about 100 mph, not exactly representative of thermal flying. Of course, if the model doesn't pull out then it must mean that the model is 'tail heavy'. When in fact both conditions don't indicate anything of value... Unless you are checking to determine tail boom flex, stab twist, or maybe pushrod flex from the huge loads (in comparison to thermal turning) experienced in the dive.

Balancing a sailplane has to be done in the airspeed conditions that most match the task and don't apply unusual load forces: flat and level flying, at airspeeds that best equal those seen during thermaling. That's where the inverted test shines. You simply flip your sailplane upside down and if you don't need any down elevator, it means that you weren't using up elevator to keep your sailplane level right side up. It means your elevator was being used to hold up excess nose lead.

So where the heck does this 'nose heavy planes are more stable than a 'neutrally' balanced sailplane' come from? It came about because it is true. Sort of.

Planes with too much nose weight have to fly with up elevator; that way when they slow, drop, speed up then they self recover. Sure sounds good. They also go up 'better' in lift. Because, it is better to fall upwards in lift.

So what's the catch? The catch is that those models really fly great, at a very *specific*, single airspeed. And that means problems. During landings, when you are coming in through ground effect and your sailplane speeds up, up goes the nose. When you are coming in and going slow, instead of stretching that glide, the elevator runs out of power and the nose plops to the ground. In tight, tiny and low thermal turns when you are scratching to make time, your model is less than efficient, needing a lot more energy than one that is not flying with lead and a dirty elevator.

So nose heavy gives you one good thing and a whole bunch of lousy things. Doesn't sound so good to me.

IF you are considering moving up toward the top 5, then you'll have to get your partner tuned up to the task. That means balanced for battle versus just for a day of soaring.

You don't need a 'better' plane, you need to learn one plane, and learn to interpret what it tries to tell you in lift and sink, and to know what that one plane will do at speed and lack of speed. The only way that will happen will be to get the plane you own to start flying more consistently. The only way you'll get that is if you get the excess lead out of its nose.

So get upside down and start mining for lead!

See you next trip where I will tell you how to get rid of waggle, but doing some wiggle: 'Setting Aileron Differential'.

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TECH TOPICS

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Repairing Wing Indexing Holes

After a long hiatus from competition, my trusty Laser 3MC was put back in the air a few weeks ago. I had forgotten what a real pleasure this ship is to fly. So I decided to give it a good overhaul to finish up the contest season in our area.

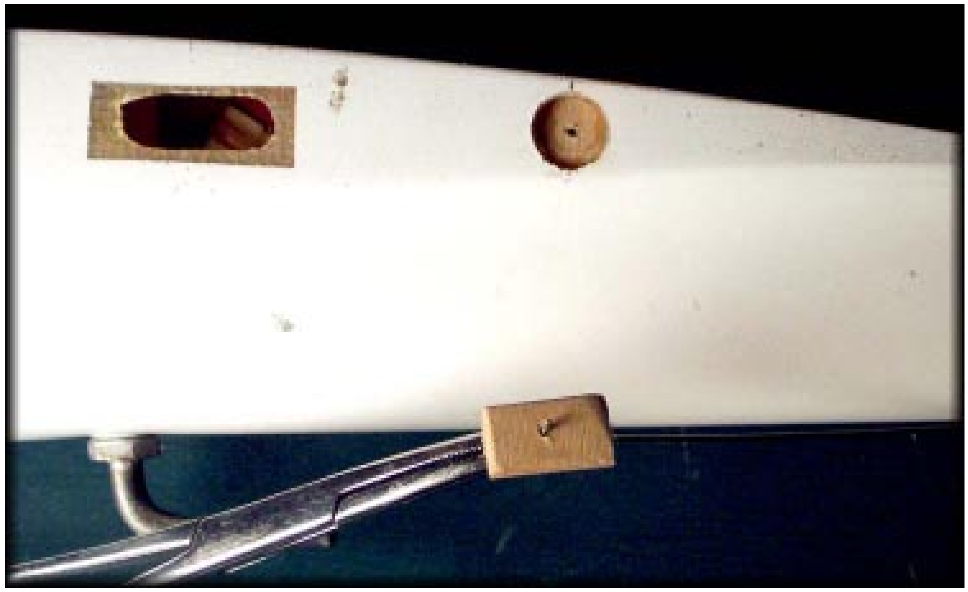
After re-covering the tail, re-taping the hinges, centering the horizontal stab, re-wiring the wing connectors and a few other items, I came to a more difficult problem - aligning the wing indexing holes in the fuselage.

Many plug-in type wings use an aluminum or carbon wing rod and then a smaller indexing rod and hole to align both wings properly when mounted to the fuselage. After almost 5 years of hard service, the holes in the fuselage had become 'egged' and allowed the wing incidence to slop around a bit.

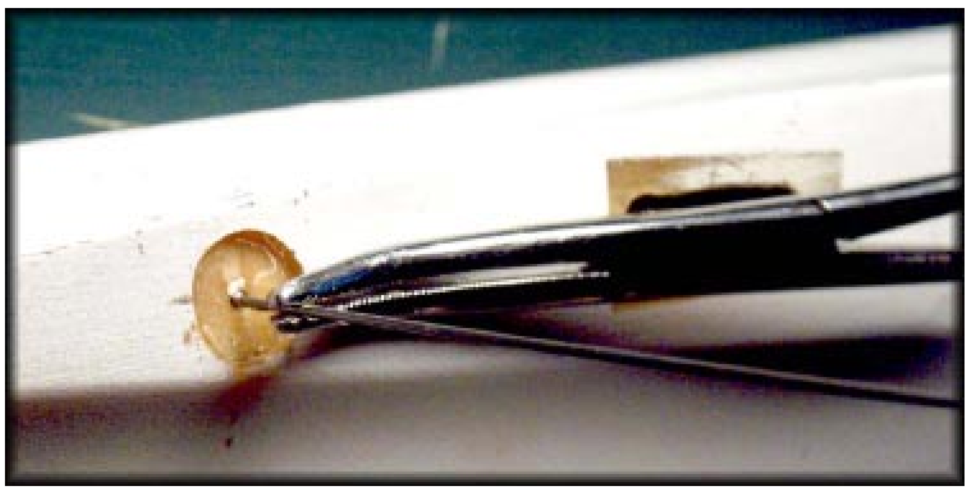
Since these holes require careful alignment and sizing, a bit of thought went into the process before tackling this job. The procedure used was very successful and a brief description follows.

The original 1/8 inch holes had grown to about 3/16 inch over the years. To get them back where they should be, the fuselage was drilled out for a 3/8" hole centered on the original alignment position. Then a piece of 3/8 x 0.75 inch plywood (1/16 inch thick) was cut for each fuselage side.

The 3/8" width allowed the ply to slip through the hole in the fuselage. A small hole drilled through the center of the ply piece allowed it to be captured by a piece of thin music wire and pulled back against the inside of the fuselage. Some epoxy was applied to the overlapping regions and the ply was re-centered behind the 3/8" hole



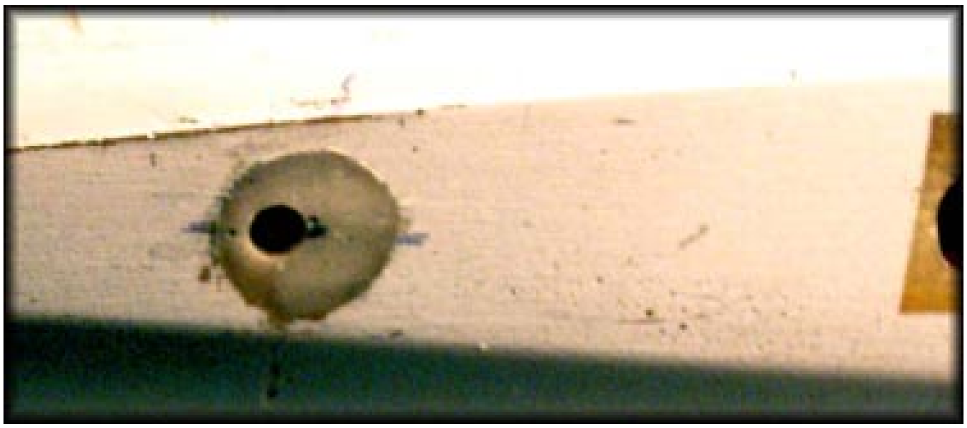
Plywood backing plate with retaining rod.



Plywood plate held in place with hemostat.

Re-filled hole ready for drilling.

Plywood template in place ready for drilling.



Finished and ready to go (could use a little paint).

and snugged up against the inside of the fuselage using a pair of hemostats.

After the epoxy set, additional epoxy was mixed with microballoons and used to fill the hole(s). After that mixture has set, the excess can be cut flush with a razor blade. You now have a new fuselage surface for drilling your indexing holes.

A template was made with 1/64 inch ply (I'd suggest 1/32 inch next time). Sandwich the template piece between a couple of pieces of scrap pine and then drill the support rod hole. In my case, that's 0.5 inch diameter. By sandwiching between some scrap wood, you'll get a very clean hole in the template.

Apply the template to the wing root using the support rod. Locate the approximate area where the indexing rod will be located and then drill a 0.25 inch hole in the template in that location.

Using a small scrap of 1/16 inch ply about 3/8 inch long as an indexing plate. Drill a hole in the center that meets the tolerances of your alignment rod (1/8 inch in my case). Now slide this small piece of ply down the indexing rod to contact the wing root. Slide in the wing rod, put the template back on the wing root, and align the 0.25 inch hole over the indexing rod with the small piece of ply centered on the 0.25 inch hole. Once it's aligned, tack the ply indexing plate to the template with CA. Voila - a perfectly aligned drilling template.

Transfer the template to the fuselage. Use the wing rod to lock down the front end of the template. Align the indexing hole in the desired location (usually centered in the wing root). Tape it down solidly so it won't slide around and then drill out the glass filled epoxy with an appropriate drill size for your alignment rods. Since my wing rod has a 5 degree angle, I also set the base of my drill press to match the correct entry angle for the wing alignment rod.

Once you're done, you might hit the new alignment hole with some thin CA to add a little surface hardness. Maybe a small patch of light glass would be in order. Be sure to re-size the hole with the appropriate drill (by hand at this point) if you use glass and/or CA to stiffen the surface.

Hopefully the pictures help walk you through the process. It's quite easy and has resulted in a wing fit and alignment that's taken the old 3MC back to when it first came out of the box.

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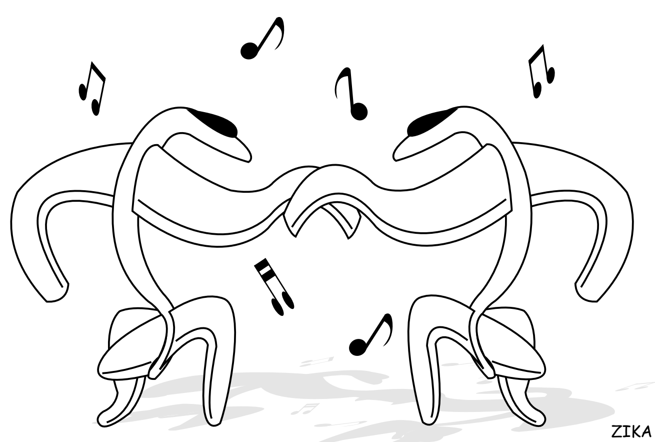

THE NATURAL SIDE OF THERMAL SOARING

by Lee Murray
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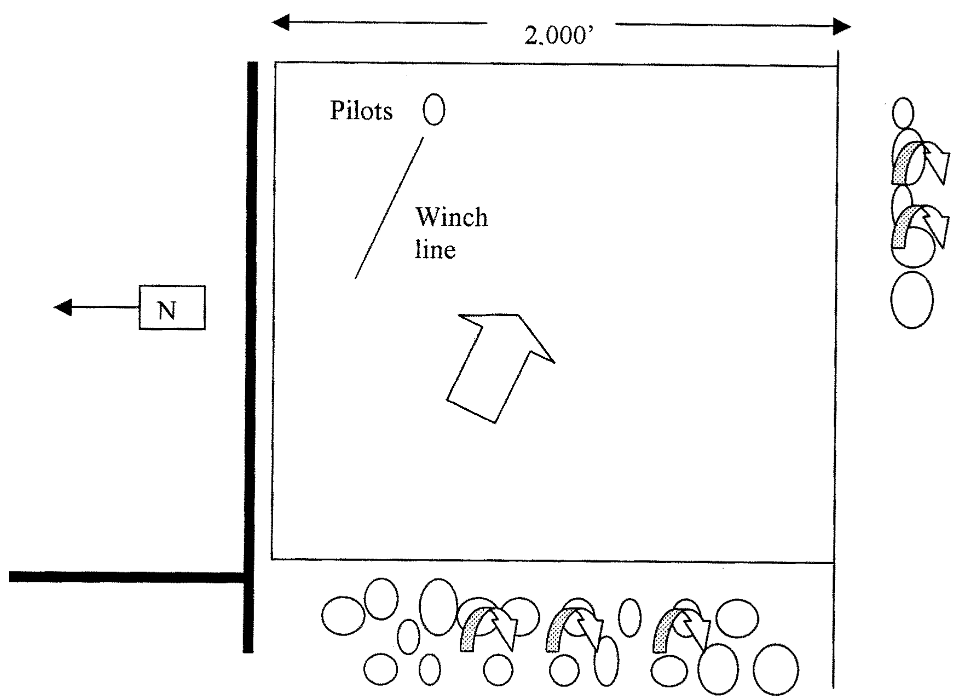
The weather for the last week in July and the first half of August in NE Wisconsin was quite stagnant due to some high pressure areas over Canada that kept the jet stream in a stationary winter pattern. During late July a stationary low-pressure area kept waves of rain coming through each day mixing moist Gulf of Mexico air with cold Canadian air. There weren't many flying opportunities until the stationary low pressure system changed. Since then we have had long periods of high pressure that brought some great soaring with some unusual conditions. On Saturday Aug 9th, the day before the 20th annual Appleton Sailplane Contest, I was out practicing with my Foamy Highlander. The lapse rate was very favorable with low wind speed and the thermals were being topped off with small cumulus clouds. It was a great day for finding thermals and teaching new fliers how to recognize them. That was a day as we have learned to predict would be good based on weather information (via lapse rate and temperature predictions) and common observations (clear skies the night before and partly cloudy skies predicted with light and/ or variable winds). Sunday, the day of the contest, was a different scenario with opportunities to discover some new facts.

Tree Thermals

I hear some of you saying, "Good Grief, Lee. Are you really suggesting that those green things can create thermals?" Yep! I know that green vegetation seems to suck the models out of the sky. The experts would say that green vegetation including trees produce evaporative cooling so they are unlikely to generate a thermal. I have discovered evidence that this isn't always the case and under special conditions they produce amazing lift.

Sunday came with a forecast of clear skies up to about 3 PM when some thunderstorms were expected to come in from the north. A heavy dew lay on the sod farm surface and was present till about noon. The contest started at 10 AM and we completed one round per hour finishing at 3 PM. The skies remained cloudless during the contest because the lapse rate kept the mixed boundary layer from rising above 3,000 ft. while the dew point was too low to form clouds.

The contestants used different approaches to extending their flights. The huge sod farm was wet and the lift from it was almost neutral for the first four rounds. An asphalt road adjacent to the sod farm is usually good for small thermals and the intersection about a 1/2 mile away is often productive. But that intersection was upwind so only the faster ships were able to get out there. Only a few fliers recognized that the trees would be drying first and could be the source of lift even in the absence of significant wind. The two tree lines were about 1/2 mile away. When I got there, the lift was so sharply defined that my Unlimited Class Prism had to be flown with full ailerons and elevator deflections to use the lift. Last year's WI State Soaring Champion, Matt Barbian, gave up the tree line strategy thinking he must be flying badly being out so far. It took concentration to keep the wings relatively flat while circling in the turbulent lift. Although the wind speed where we were standing was 0-5 mph, the model over the trees would jump up 8 feet at a time. In summary, check out the tree lines when looking for morning lift on wet fields.



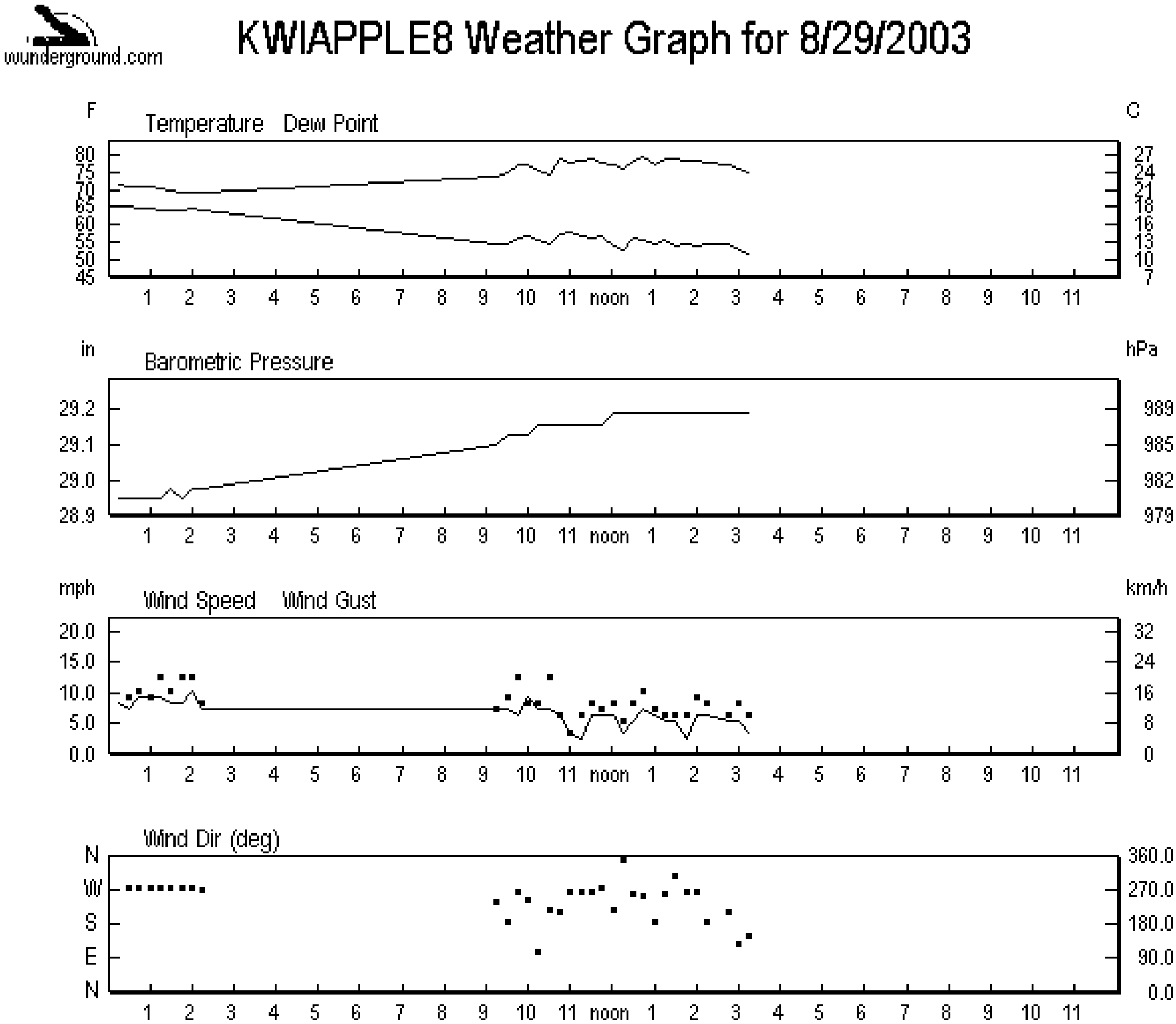
Internet Weather Links

My friend Greg Ciurpita was kind enough to forward some links to Wunderground / Underground Weather information. The information comes from government and personal weather station information. Individuals can volunteer to participate in the program to provide data from their homes or places of work.

This explanation appears on their web site:

> The Weather Underground has teamed up with Ambient Weather, Weather Display and Weather View 32 to build a network of weather stations. Anyone with a weather station supported by the software listed … can upload his or her weather data to The Weather Underground. This data is accessible by anyone via The Weather Underground Web Site.

To access the information, simply go to the Wunderground web site, enter the airport code, city & state, or zip code of where you want information and it comes right up. The link provides wind direction and intensity, gust information, cloud cover and visibility, as well



as other information. This would be great for slope soaring. Know before you leave what is happening at the slope. In some areas there is data available from a Personal Weather Stations link on that same web page lower down. These can be places that are right around the corner or close to that remote flying site you go to. The Personal Weather Stations provide plots of what is going on that day. The gust and wind direction can tell you lots about how much thermal activity is going on and the frequency of reporting is typically much more frequent than government sources.

The Underground Weather **History** can be obtained different ways. If you go to the Personal Weather Station Listings page (address shown below) you can find the best weather station for your use. Use that station identifier in accessing the Wunderground Weather Station History. Then save that as a web browser favorite or book mark and you will have a quick local weather history of temperature, dew point, barometric pressure, wind speed, gust speed, wind direction, by time of day. Greg points out, “What’s interesting to me is the resolution of the data for some personal sites. It’s collected more frequently than every hour, and provides wind speed, gust and direction.” There are also buttons for bringing up the plots for the last week or the last month.

In my area I can find Personal Weather Station History scrolling down on the Underground Weather page for Appleton, WI. That feature may not be available in your area. KWLAPPLE8 is a Personal Weather Station located at the Fox River Mall just 6 miles east of our flying site. KWLAPPLE8 doesn’t have data every day. That seems to vary with the station, but what a bonanza! Perhaps this can be the topic of yet another article.

Thanks Greg! I bet many modelers can make good use of this.

Links Referenced:

Wunderground Weather
http://www.wunderground.com

Personal Weather Station Listings
http://www.wunderground.com/weatherstation/ListStations.asp

Wunderground Weather Station History
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWIAPPLE8
Note that the information after ID= is the station identifier obtained from the link above.

Weather Station Software & Equipment
http://www.weather-display.com/
http://www.ambientweather.com/
http://www.weatherview32.com/

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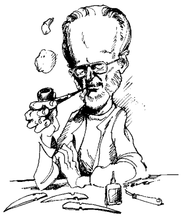

Jer's Workbench

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Travel with a Sailplane

Do you have a sailplane? Do you like to travel but have no place to go this summer? Why not visit Northern California? There are a lot of things to see and do, plus there are places to fly.

Sacramento, California

Let's start with Sacramento, California. One can take a drive up into the foothills and visit the Gold Country; then, drop down into Sacramento to visit Sutter's Fort, the California State Capital, and an area called 'Old Sacramento'. And, a 20 mile drive west out of Sacramento on Highway 80 leads to the Sacramento Valley Soaring Society (SVSS) flying site.

It's worth the trip! They have a beautiful flying field, the members are friendly, and they have good equipment, too! Should any of you find yourself out Sacramento way, you can check on the club schedule of events by contacting Dudley Duford at dudley@jps.net or telephone (916) 991-1266.

San Francisco, California

From Sacramento, still on Highway 80, let's head west to San Francisco to walk the streets of China Town and hop on a cable car headed for Fisherman's Wharf. Now, this is an action packed tour and once ready to hit the road again, it's off to the north and a ride across Golden Gate Bridge.

Muir Woods

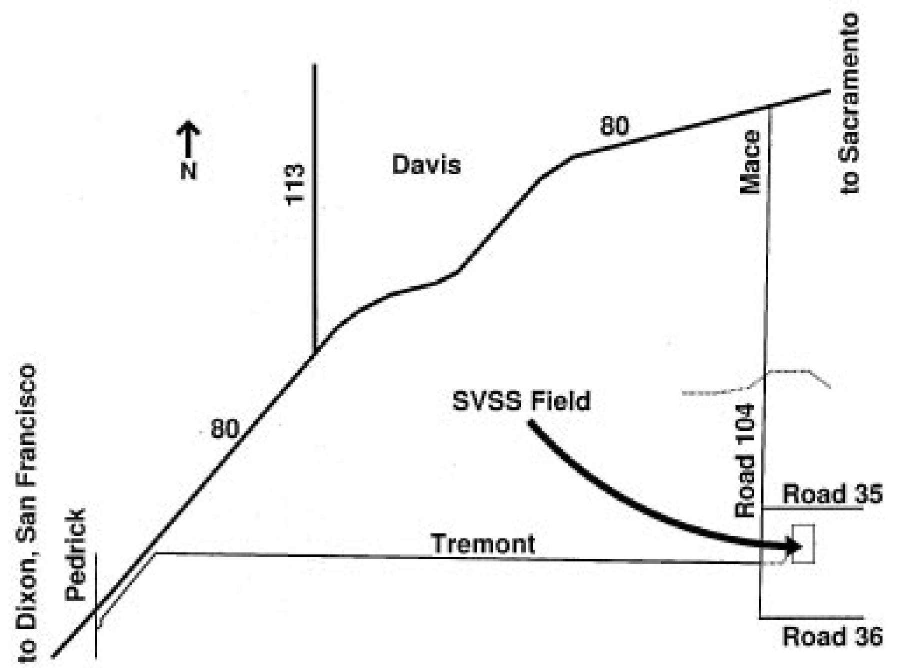
About 3 miles north of the Golden Gate Bridge a sign signals a turn off for Highway 1 North. It leads to Stinson Beach and Muir Woods. After about 10 minutes of driving time, there is a sign for Muir Woods. Turn right, continuing to the top of the hill, about 1/4th of a mile. There is a parking area on the west or left side of the road. If you reach an intersection, you went too far. Turn around, parking on the right side of the road.

Taking a well marked trail, for about 40 yards, leads to a spectacular view. This is a state park, there is no club that I know of, and there are lots of folks who come up here to slope fly. If there isn't any wind, continue on up the road to Muir Woods and take a hike through the Giant redwood trees.

Napa Valley

Another area worth seeing on this trip, of course, is the Napa Valley Wine Country. So, we need to pick up Highway 29 on the north end of San Francisco Bay.

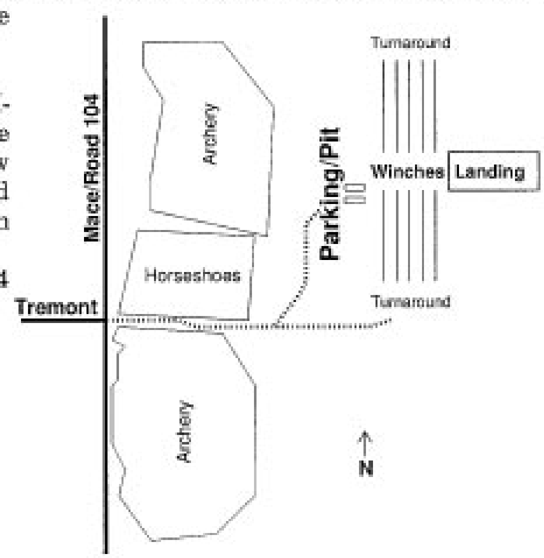
Driving north on 29, between Napa and Calistoga, the landscape shows off some of California's finest vineyards with tours and, of course, tasting



The SVSS flying site is located at Yolo county's Grasslands Regional Park south of Davis, CA.

Directions: From I-80, take the Mace Blvd. exit. Follow Mace south 4.0 miles. The gravel driveway entrance is directly opposite Tremont Rd. Follow it into the park for approximately 200 yards past the horseshoe and archery areas to the field.

Shortcut for eastbound I-80: From I-80, take Pedrick Rd. exit. Follow the frontage road eastbound on the south side of I-80 for 0.8 miles. Take Tremont east for 5.4 miles.



After a short 40 yard walk from the parking area, you could be standing in this picture at Mount Tamalpais.

Clear Lake Modelers flying site. Tom Overton enjoying a few good thermals.

rooms. But, beware! Keep your credit card(s) handy and some spare space in the car, because you might spot a few antique stores along the way!

Clear Lake Modelers

From Calistoga it's only 30 miles to Clear Lake. Between the small towns of Lower Lake and Kelseyville on Highway 29 there is a flying site for the Clear Lake Modelers. A really nice place to fly, there are too many thermals to count. The club hosts a mix of gliders, electric and gas powered models, all using this great site.

If you're hoping to drive up and drop in unexpected, sorry. The site is on a working ranch, so there's a locked gate followed by a mile of dirt road. The flying site can't be seen from the highway.

If you find yourself in the area and would like to visit, contact Doug Skjerseth at dest101@proseth.com or call Doug at (707) 928-4619. It's worth the trip! And, don't forget your AMA card!

•••

SVSS flying site. Phil Bauer Launching his Blue Bunnie.

Skin Sizing of Stressed-Skin Wings

Mark Drela revised 06 May 03

A stressed-skin composite wing, which has the skin taking most of the bending load, will typically fail by local buckling or "face wrinkling" of the top compression-side skin. The failure stress can be estimated by established theoretical formulas, such as those obtained from the following Mich.Tech.U. web site:

<http://callisto.my.mtu.edu/MY472/> (click on "Sandwich Core Structures" at bottom)

The compressive skin stress at the onset of wrinkling is given approximately by

$$\Sigma_{wr} = 0.57\ (\ E\ Ec^2\ )^{0.333}$$

where

E = skin modulus along the span
Ec = core modulus perpendicular to the surface

The formula above assumes that the skin is flat, without local dents or other defects, and is bonded well to the core. In reality, the chordwise curvature of the skin will stabilize it somewhat and tend increase Σ_{wr}, while the spanwise curvature will destabilize it somewhat and tend to decrease Σ_{wr}. Local manufacturing defects will of course decrease Σ_{wr}. In practice, some safety margin from the theoretical Σ_{wr} above is probably prudent.

Use of the formula for Σ_{wr} requires knowing the skin and core elastic moduli E. The moduli of common skin materials are:

E = 20. Msi unidirectional CF
E = 11. Msi 0/90 CF cloth
E = 2.8 Msi +/-45 CF cloth

E = 6.0 Msi unidirectional S-glass
E = 4.0 Msi 0/90 S-glass cloth
E = 2.5 Msi +/-45 S-glass cloth

E = 5.7 Msi unidirectional E-glass
E = 3.5 Msi 0/90 E-glass cloth
E = 1.7 Msi +/-45 E-glass cloth

(Note: Msi = 1 million psi)

The moduli Ec of the various foams used for cores is listed in the accompanying table "Elastic Modulus Of Common Foams" (file Foam_modulus2.txt). For any foam these can be measured by a simple benchtop experiment, as described in the accompanying sheet "Measuring Elastic Modulus via 3-Point Bending Test" (foam_stiffness.pdf). The core modulus Ec in the wrinkling criterion above corresponds to the thickness-direction modulus from the table:

Ec = E33

Three-meter glider skin-sizing example...

E = 20 Msi uni CF skin
Ec = 3000 psi Foamular 400 pink foam (E33)

$\Sigma_{wr} = 0.57\ (\ 20*10^6 * 3000^2\ )^{0.3333} = 32200$ psi

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chosen upper skin stress: $\Sigma_u = 29000$ psi (0.9 x Σ_{wr})
chosen lower skin stress: $\Sigma_l = 150000$ psi (tensile failure)

wing span : b = 130 in
wing load : F = 150 lb (winch line force)

* At wing center (at span fraction τ=0), MH32 (T/c=0.0866) ...

moment factor: a = 0.95 (picked from table below. at τ=0.00)
stress factor: f = 0.0449 ("Ixx/t(Y-Yc)" from Xfoil, approx. 0.5*T/c)
chord : c = 10 in
bending moment: M = a b F/8 = 2315 lb-in
skin load : $P = M/(f\ c^2)$ = 515 lb/in

minimum upper skin thickness: $t_u = P / \Sigma_u = 0.0178$ in (4 layers)
minimum lower skin thickness: $t_l = P / \Sigma_l = 0.0034$ in (1 layer)

* End of center panel (at span fraction τ=0.45), MH32 (T/c=0.0866) ...

moment factor: a = 0.25 (picked from table below at τ=0.45)
stress factor: f = 0.0449
chord : c = 9 in
bending moment: M = a b F/8 = 579 lb-in
skin load : $P = M/(f\ c^2)$ = 159 lb/in

minimum upper skin thickness: $t_u = P / \Sigma_u = 0.0055$ in (1+ layer)
minimum lower skin thickness: $t_l = P / \Sigma_l = 0.0011$ in (1 layer)

Approximate tip deflection...

* Actual situation at wing center

bending moment: $M = 2315$ lb-in
stiffness factor : $k = 0.002097$ ("Ixx/t" from Xfoil, approx. $0.28*(T/c)^2$)
chord : $c = 10$ in
upper skin th.: $t_u = 0.0180$ in (4 layers)
lower skin th.: $t_l = 0.0045$ in (1 layer)

effective thickness : $t = 2\, t_u\, t_l / (t_u + t_l) = 0.0072$ in
section bending inertia: $I = k\, c^3\, t = 0.0151\ \text{in}^4$

spanwise beam curvature: curv = $M / (E\, I) = 0.00767$ / in

tip deflection: $d_{tip} = \text{curv}\, b^2 / 8 = 16$ in

This d_{tip} assumes a constant spanwise curvature. Because the outer parts of wing are likely to have an "oversized" skin, the actual tip deflection will be somewhat smaller.

Appendix

The load factor "a" gives the spanwise distribution of bending moment, relative to the center value on a uniformly-loaded rectangular wing. The "a_{uni}" column is for the uniformly-loaded wing. The "a_{ell}" column is for an elliptically-loaded wing. Virtually any wing will fall somewhere between the two columns, depending on the amount of chord taper and twist.

For spreadsheet implementation, the following formulas will be more convenient:

$$a_{uni} = (1 - \tau)^2$$
$$a_{ell} = 0.8488*(1 - \tau)^{2.4}$$

It is suggested that the following combined formula be actually used:

$$a = (1-k) * a_{uni} + k * a_{ell}$$

The parameter "k" interpolates between the two limiting cases...

$$k = 0.0 : a = a_{uni}$$
$$k = 1.0 : a = a_{ell}$$

It is then only necessary to specify "k" from the range 0.0 - 1.0 . "Safe" planforms with broad tips will be close to k=0.0 , while "aggressive" planforms with strong taper will be close to k=1.0 .

t	a_{uni}	a_{ell}	
0.00	1.0000	0.8488	root
0.05	0.9025	0.7520	
0.10	0.8100	0.6615	
0.15	0.7225	0.5774	
0.20	0.6400	0.4996	
0.25	0.5625	0.4280	
0.30	0.4900	0.3626	
0.35	0.4225	0.3032	
0.40	0.3600	0.2498	
0.45	0.3025	0.2022	
0.50	0.2500	0.1603	
0.55	0.2025	0.1240	
0.60	0.1600	0.0929	
0.65	0.1225	0.0669	
0.70	0.0900	0.0458	
0.75	0.0625	0.0292	
0.80	0.0400	0.0168	
0.85	0.0225	0.0082	
0.90	0.0100	0.0030	
0.95	0.0025	0.0005	
1.00	0.0000	0.0000	tip

Numerical Understanding of Planforms

Greg Ciurpita

Many model RC articles and books qualitatively discuss various aerodynamic concepts. These articles explain fundamental concepts without going into too much detail. But I find it difficult to fully understand some concepts without seeing real numbers. While one design aspect may be relevant, another may be more important. For example, we know that:

- An elliptic wing planform is ideal in terms of uniform lift coefficient across the span,
- Airfoil drag decreases with Reynolds Number,
- Reynolds Number increases with chord length,
- But that the above lead to a design conflict at the wing tip where the ideal calls for narrow wing chords, resulting in low Reynolds Numbers and presumably higher drag.

An important question is how much worse is the drag because of the smaller wing tip chords?

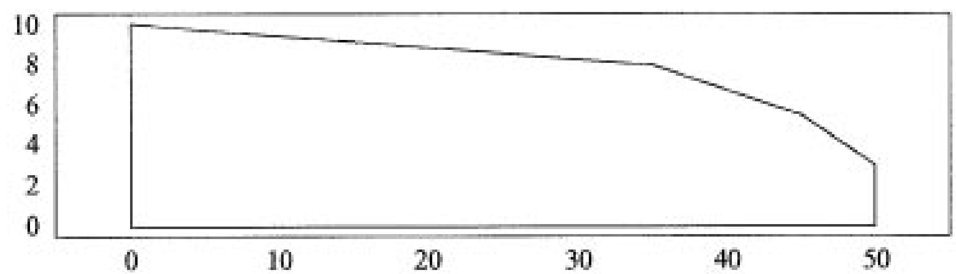

Figure 1 - Planform

Span Position (in)	0	35	45	50
Chord Length (in)	10	8	5.5	3

Figure 1 illustrates a three section planform that attempts to have the uniform lift coefficient of an elliptic planform. This tapered planform has an area of 807.5 sq.in. The tapered planform will be compared to a non-tapered planform with a constant chord of 8.1" chord and a comparable wing area of 810 sq.in.

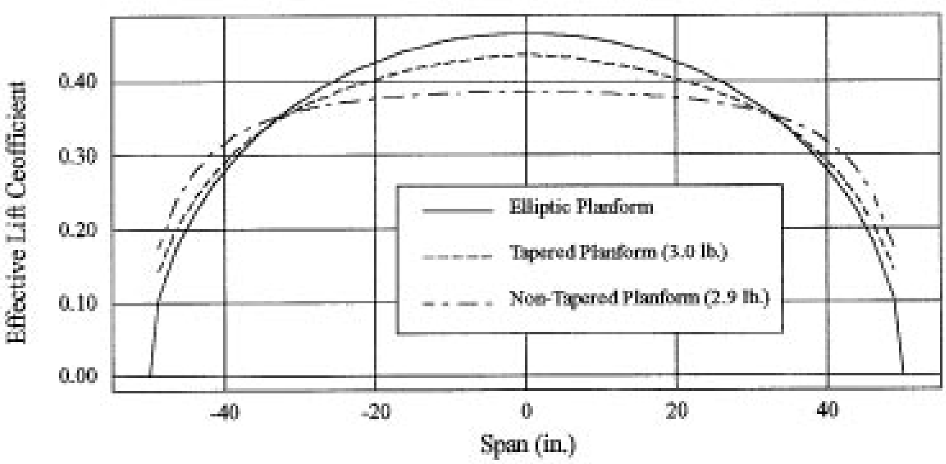

Figure 2 - Lift Distribution

Figure 2 illustrates the lift distribution for the tapered and non-tapered planforms described above, for an airspeed of 35 ft/sec, and and angle-of-attack, 4°. The lift distribution is calculated using the Vortex Lattice Method described by Mason, Applied Computational Aerodynamics, and also implemented in John Hazel's LiftRoll Spreadsheet. The lift distribution represents the lift generated per unit (ft) of span. For example, consider the tapered distribution. It's average value is roughly 0.36 lb/ft. and results in 3 lb of lift for a 100 in, 8.3 ft span.

Figure 3 illustrates the effective lift coefficient for the two planforms. The effective lift coefficient is calculated by dividing the lift from Figure-2 at any spanwise panel on the wing by 0.5 r V^2 S_s, where S_s is the area of the wing at that point on the span (panel width · average panel chord).

While the tapered planform is not the most optimal, it results in a more uniform lift coefficient across the entire span. The effective lift coefficient of the non-tapered planform decreases rapidly near the tips. The lift coefficient decreases because the lift decreases while the wing area (i.e. chord) remains constant. The lift also decreases near the tip of a tapered planform, but the wing area is also decreasing, maintaining a more constant lift coefficient.

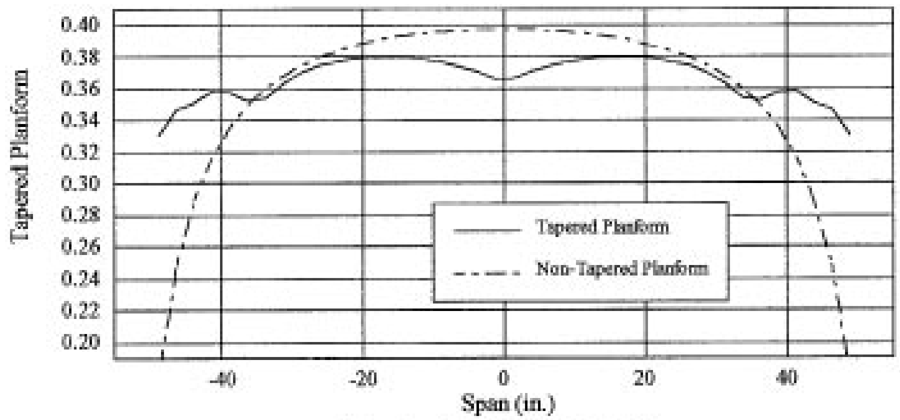

Figure 3 - Effective Lift Coefficient

The lift at any point on the wing is affected by adjacent sections of the wing. The lift at an interior section of the wing is stronger because of the lift generated on either side of that section. The lift at the wing tip is only strengthened from one side, and crossflow around the tip weakens it further. This is what the Vortex Lattice Method captures. This same affect occurs on the tapered planform near each panel break.

Figure 4 illustrates the Reynolds Numbers across the span for both planforms. It depends on airspeed, which is constant in this case, and chord. As you would expect, the Reynolds Number is constant for the non-tapered planform, and decreases as the tips narrow on the tapered planform.

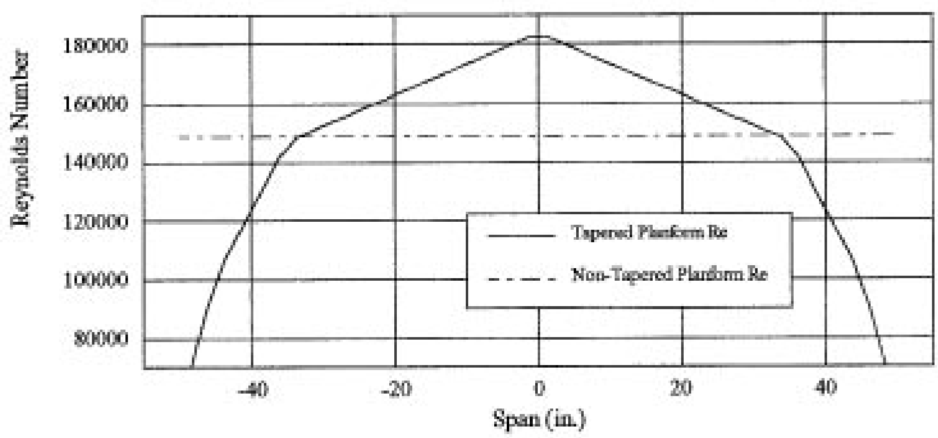

Figure 4 - Reynolds Number

Given the effective lift coefficient and Reynolds Numbers, airfoil data, from the UIUC Data Base, can be used to determine the corresponding drag coefficient. The SD7037 airfoil was used in this example, and is shown in Figure 5. It is important to recognize that since the Reynolds Number may vary across the span, different airfoil polars apply to different sections of the wing. (See "Understanding Airfoil Polars Without Math" by Kuhlman, ...).

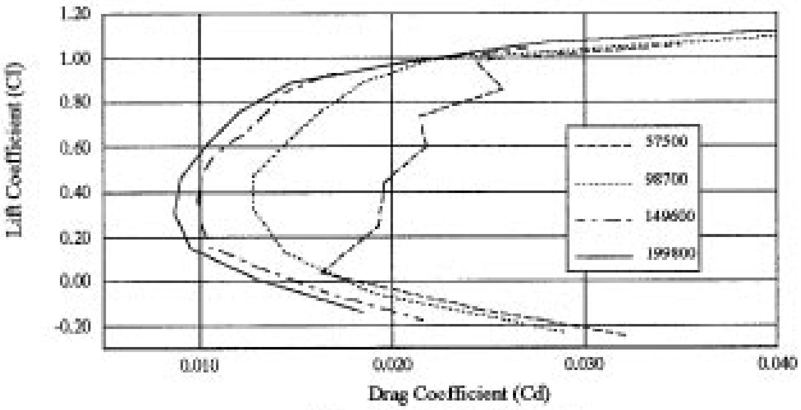

Figure 5 - SD7037 Airfoil Polars

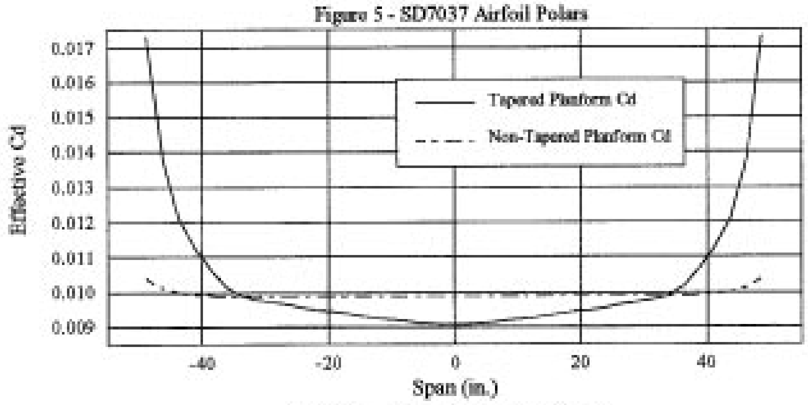

Figure 6 - Drag with SD7037 Airfoil

Figure 6 shows the corresponding drag coefficient across the span for both planforms. The drag coefficient increases significantly near the tips of the tapered planform as the Reynolds Number decreases. But the Reynolds Number is constant (90000) for the non-tapered planform, and the drag coefficient increases only slightly as the lift coefficient decreases from 0.4 to 0.2 (see Figure-3 and 5) at a Reynolds Number of 98700.

Figure 7 shows the actual spanwise drag. This is calculated from the spanwise drag-coefficient in Figure-6, wing sub-section areas, and airspeed (0.5 r V^2 S Cd). Despite the higher drag coefficient near the tips, the smaller wing tip areas of the tapered planform result is less wing tip drag than the non-tapered planform. The total drag for the tapered planform of 0.0826 lbs (1.3 oz) is only 1.2% greater than the 0.0816 lbs of drag for the non-tapered planform. And this ratio will vary with flight parameters and may result in less drag for a tapered than non-tapered planform.

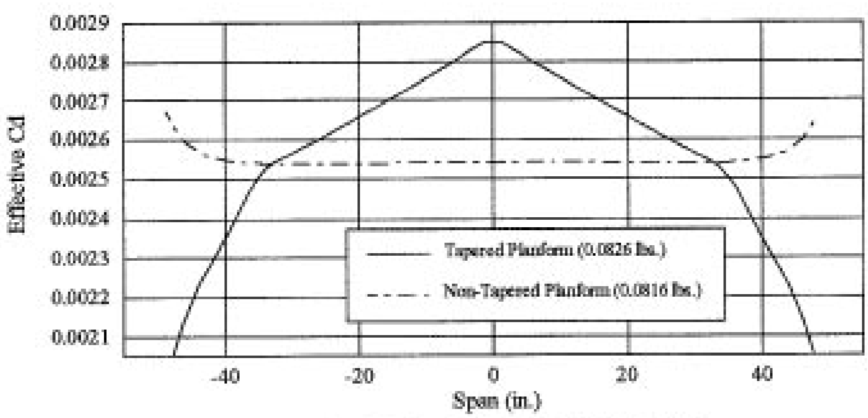

Figure 7 - Drag Profile with SD7037 Airfoil

It is interesting to see that the final results, for the given flight conditions, show little difference in total drag between the tapered and non-tapered planforms. (However, there may be other reasons to be concerned with lower wing tip Reynolds Numbers).

This note has provided a quantitative comparison of two simple wing planforms. I hope that real numbers make clear what lengthy discussions do not. With the the power of PCs, algorithms like the Vortex Lattice Method, and the UIUC Airfoils Database, there is less reason to guess. I hope these plots tie together and provide more concrete descriptions of several aerodynamic concepts. A possible future article will consider circling flight where the airspeed is not constant across the span, with corresponding affect on Reynolds Numbers and drag.

Applied Computational Aerodynamics:

http://www.aoe.vt.edu/aoe/faculty/Mason_f/CAtxtTop.html

Link to John Hazel's LiftRoll Cookbook and Greg's Java enhancement:
http://www.geocities.com/jebbushell/COOKBOOK.htm

UIUC Airfoil Database:
http://amber.aae.uiuc.edu/~m-selig/ads.html

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Reference Material

Summary of Low-Speed Airfoil Data - Volume 3 is really two volumes in one book. Michael Selig and his students couldn't complete the book on series 3 before series 4 was well along, so decided to combine the two series in a single volume of 444 pages. This issue contains much that is new and interesting. The wind tunnel has been improved significantly and pitching moment measurement was added to its capability. 37 airfoils were tested. Many had multiple tests with flaps or turbulation of various configurations. All now have the tested pitching moment data included. Vol 3 is available for $35. Shipping in the USA add $6 for the postage and packaging costs. The international postal surcharge is $8 for surface mail to anywhere, air mail to Europe $20, Asia/Africa $25, and the Pacific Rim $27. Volumes 1 (1995) and 2 (1996) are also available, as are computer disks containing the tabulated data from each test series. For more information contact: SoarTech, Herk Stokely, 1504 N. Horseshoe Circle, Virginia Beach, VA 23451 U.S.A., phone (757) 428-8064, e-mail <herkstok@aol.com>.

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Books by Martin Simons: "World's Vintage Sailplanes, 1908-45", "Slingsby Sailplanes", "German Air Attaché", "Sailplanes by Schweizer". Send inquiries to: Raul Blacksten, P.O. Box 307, Maywood, CA 90270, <raulb@earthlink.net>. To view summary of book info.: http://home.earthlink.net/~raulb

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