Radio Controlled Soaring Digest

March 2006 — Vol. 23, No. 3

CONTENTS

March 2006
Vol. 23, No. 3

Front Cover — Glenn Foster flies his *Spinner XT* against the Book Cliffs north of Grand Junction, Colorado. Sunlight was spot-lighting through the clouds and warming small areas of the cliffs. Canon G3, 1/807 sec, f7.1, 29mm, ISO 50.
Photo by Greg Luck, <www.lavawing.com>

Back Cover: Ian Frechett came all the way from Colorado to do some DSing with his *Mini Blade* at the Wilson Lake Dam near Lucas, Kansas. Nikon D100, 1/800 sec., f 5.6, 116mm.
Photo by Greg Smith, <www.slopeflyer.com>

R/C Soaring Digest

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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 each article is 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.

In the Air!

The *Genie* article that starts on page 12 of this issue is the result of an e-mail message from *RCSD* columnist Mark Nankivil. Mark was looking over Harley Michaelis' *Genie* web pages during a lunch break and, enthralled by what he saw and read, he immediately wrote an e-mail to us in which he proposed a *Genie* construction series for *RCSD*. We wrote to Harley, and he responded positively to the idea. As this issue is being published, Chris Boultinghouse has volunteered to be lead writer and photographer for the construction series. While Chris gathers materials and gets ready to start building, we'll include some introductory material in this issue to whet the appetites of *RCSD* readers.

We've been visiting Greg Luck's Lavawing web site <www.lavawing.com> for some time , initially induced by his movie "PopFly" which features astounding footage of Michael Richter's *Alula* SAL EPP 'wing flying in Hawaii. Since our first visit, Greg has added a number of new movies, more recently some great videos shot near his new home in Colorado. The front cover of this issue is a still photo taken by Greg on a recent slope outing, and there are more photos from this excursion to accompany Greg's article which starts on page 4. You're stuck in place but your mind is wandering? Wander further with Greg's Bikeabout web site <www.bikeabout.net>.

Phil Pearson, of *Encore* HLG fame, recently gave a two part presentation on "how to build an *Encore*" to the Seattle Area Soaring Society. Phil has graciously provided all of his presentation materials to *RCSD* for publication in this and future issues! We know *RCSD* readers will be looking forward to each installment.

That's not all, but it's time to build another sailplane!

Winter in the Valley

Gregory Luck, <bikeabout@mac.com>

Yesterday morning the world was a soft white blanket, with more falling from the winter sky. Slippery slopes, fickle winds, and enough moisture to turn the trails into quick-set mortar. I stayed in town.

Wet storms don't last long here in Colorado's Grand Valley. The sun burned back by noon, and by evening, when I went out to throw my hand-launch in the street, the snow was mostly gone.

First thing this morning, check the weather report. SE at 15. Leap out of bed and into clothes. Warm clothes? 31˚F, which is practically a heat wave when days have started in teens and low 20s for weeks. But the wind... So yes, warm clothes.

Glenn is taking his truck and his dog. A quick romp before work. I lead a less structured life and throw my bicycle in the back, under the planes, so I can stay longer. Dash out of town, onto the dirt. Bump toward the ridge which looks dark and maybe wet under a sky bandaged white with a gauze of clouds where blue soaks through.

As usual, there is no sign of wind from inside the truck. Nothing out there to make it show itself. Short grass. Stiff, leafless brush. Low, pale rocks, glowing with orange lichen. Waves of dirt hills. Distant high rock cliffs. Then we're out of the truck. Out with the dog. Out with the planes. Out with the bicycle. Out into the wind, strong enough to make us smile. Cold enough to make us question the numbers.

Warmth comes from the climb. Dry at least, despite yesterday's snow. We put our boots to the trail and they return to us light and free of mud. Up the roller coaster of grey dirt. Base Camp IV. The Hillary Step. And finally, the Summit. Top of the world, or our world. The wind is good, the planes eager to leave our arms.

Switches on. Motion checked. Glenn pulls back and throws. A white *Spinner* arcs into the void, and the void throws it upward. I know before I ask. "Is there any lift out there?" He rolls out of inverted, pulls a turn and comes back fast along the edge of the slope. "I'm not sure." I laugh and step up. A yellow *Spinner* arcs into the void, and the void throws it upward.

Brains in planes, we speed and loop and roll through the sky. We trace our own threads, unreeling spools of nothing in the invisible air. Then we gather our threads together, passing near and close, then closer. Weaving a fabric for the camera, which is running, tempting us. Closer. Closer yet, with a roll as I go. Again! But closer this time.

The planes come by together, but my roll is clumsy. For a moment, earth and sky mingle, as the dust of earth reaches into the air, plowed by the nose of my plane. But the dirt is soft, the plane is strong enough. One bounce, the gritty cloud is already clearing, the plane falling outward, reaching again toward the open sky. While we, standing firm above it, are laughing and and grinning as it is thrown upward into the void where we speed and loop and roll.

Glenn's life is calling him. He lands and gathers his things. Next I see him, he is hiking down the grey trail, transmitter in hand, plane in the air, flying like he can't get enough. Soon he is gone and I fly the lonely sky.

I land and move my things to the razor ridge of The Scythe. Here the sky is divided. One side of the cutting edge will throw my plane to the sky. The other side will throw it to the ground. But if I can fly between the lines, the wing will squeeze speed out of the differences. Too much wind for the *Spinner* to fly the line. I measure to be sure. Average is about 25 m.p.h. I throw the *Predator Bee* out. Fun on the front side, but each time I dive to the back, the speed gets ahead of me. Wildly out of control, I fight back under the edge and slip over into safety.

Glenn Foster flies his *Spinner XT* through the winter sky off Raven Ridge, north of Grand Junction, Colorado. *Spinner XT* designed by Ed Berg, kit by <www.laserarts.com>. Photo taken December 12, 2005 by Gregory Luck/www.lavawing.com.

I fly the front side, carving the bowl, peeling away the air as it rolls up the slope. The *Bee* is probably heating with the friction, so I send it out into the bigger sky to cool, into view of the cliffs. There is a dark edge to the valley. Changes are moving through the atmosphere. The wind is calming but not gone.

I bring in the *Bee* and send the *Spinner* back into the sky. Now I can fly the line between front and dark. I stitch the front to the back with easy circles. I move freely from one side to the other. I pull long cords down the ridgeline. I carve deep lines in the bowl. I trail ribbons into the wide sky to see how far away it will hold me up. Then into the back side again, to pull everything tight.

The day is not warming. Iron plates are rolling across the roof of the valley and the wind is fading away. With a couple go-arounds and a fist-full of spoilerons, I bring the S*pinner* in for a hand catch. I pack to go. Unusual, in that I'll often fly until there isn't any lift left and I end up scratching hard and hiking for the plane. But today I'm calling it good. And measured by my grin, it has been.

I hike down the grey trail, load my bicycle with my planes, pound the pedals, and fly down the gravel road like I can't get enough.

A now "classic" *Seeker* SAL glider flies from Orchard Mesa over Palisade, Colorado. Mount Garfield in the background. Pilot: Glenn Foster. Builder: Gregory Luck. Kit formerly from <www.liftworx.com>/Scobie Putchler. Photo by Gregory Luck/www.lavawing.com.

Peter Wick on Planks

by Peter Wick, <and-wi-pep@parknet.dk>

Part 3: The good slope plank

Planks are very good concept to get an easy to build plane, with very good performance and handling on the front side of the slopes.

What you have to do:

1. No fuselage (if possible).
2. Design C_L should be around zero, which comes with an airfoil with a moment coefficient of around zero, and the minimum drag of the airfoil should also be around zero.
3. A very low static margin.
4. Central fin.

Why?

1. First, no fuselage means no fuselage drag.

Second, the fuselage is adding some negative moment, so you will have to compensate with negative (upward) elevator deflection. This costs lift and is adding airfoil drag.

If you have to have a fuselage, make it as symmetrical as possible.

2. By having the design C_L close to zero, you get a plane with very low drag at high speeds. That is actually where the airfoil drag plays the most important role, especially because the rest of the drag is very low on a plank. I think it is possible to come up with an airframe that has some advantages at high speeds in comparison to conventional concepts.

3. Maximizes lift and minimizes both the inertia along the pitch axes and the profile drag.

4. A single central fin minimizes the inertia along the lateral axes and has lower drag than winglets at high speeds.

The airfoil has therefore low camber, around one to two percent, and is designed for negative flap deflections only. The airfoil should be rather insensitive to laminar separation and the moment curve (moment coefficient vs. angle of attack) should be almost constant, even with flap deflection.

This is in my opinion the way to get superb handling qualities and good performance, because they allow you to fly with a very low static margin. If this sounds quite complicated, here an example:

Our model plank gets equipped with three different airfoils (see Figure 10):

CJ-3309 — representing the old plank design concept of a thermal plank

Phoenix — representing a more modern approach to a thermal concept

EH 1.5/9 — representing an old, but still often used, more F3B directed fast plank or swept back flying wing airfoil

Flap chord is 25% along the whole span. The moment coefficients are, according to Eppler: c_{m0} (CJ-3309) = +0.019, c_{m0} (Phoenix) = 0.01 and c_{m0} (EH1.5/9) = 0.

At our now famous cliff, flaps at neutral, all planes have a static margin of 5%, we would expect the following:

EH 1.5/9.0 only stable in a vertical dive ($c_l = 0$), therefore the airfoil is more used in swept back flying wings.

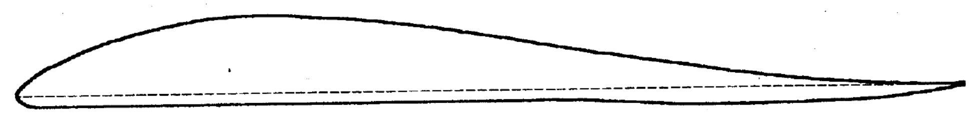


Figure10a: The CJ-3309 airfoil, a representative of the old school plank airfoil family.
Camber = 3.4%, Thickness = 9.2%

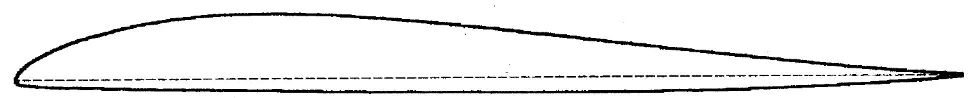


Figure 10b: The Phoenix airfoil, one of the best airfoils for planks.
Camber = 2.78%, Thickness = 8.19%

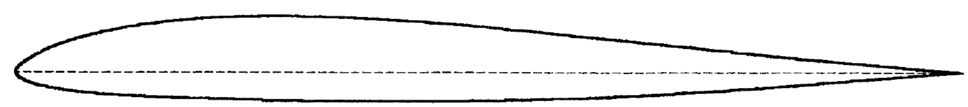


Figure 10c: The EH 1.5/9.0 airfoil, mainly used on flying wings with sweep.
C amber = 1.5%, Thickness = 9%

The Phoenix will be flying at $c_l = 0.2$, a fast glide.

The CJ-3309 will be flying at $c_l = 0.38$, which means around the best gliding angle.

(Text continued on page 11.)

Figure 11: Sink polars for our model plank with a static margin of 6%

Comments:

The polars for the plank with the CJ-3309 airfoil could not be fully completed because it was not possible to produce the necessary pitching moments.

The sinking speeds are 17.3" per second for the Phoenix airfoil and 18.9" per second for the plank equipped with the EH 1.5/9 airfoil.

The Phoenix airfoil reaches its minimum sinking speed at minimum speed, which is favorable in thermal circles.

The range of low sinking speed is broader for the EH airfoil and shifted to higher speeds.

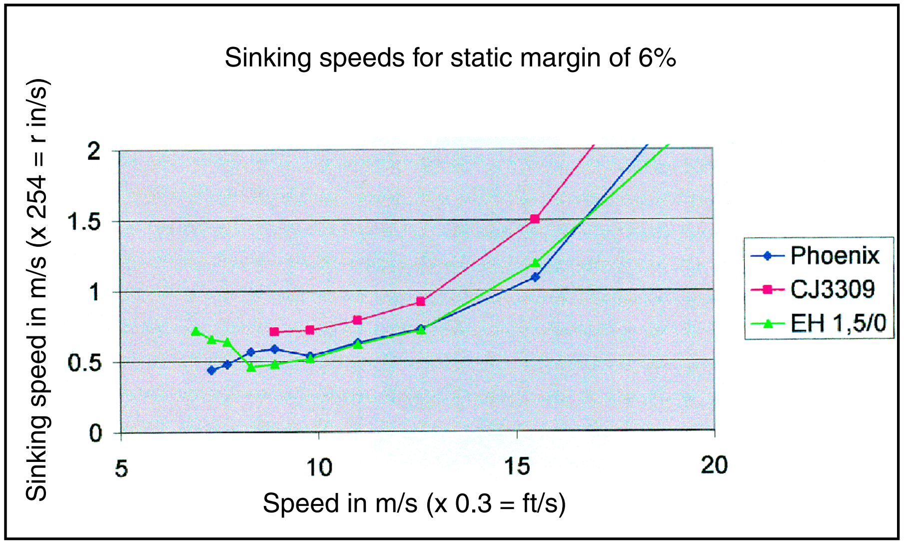


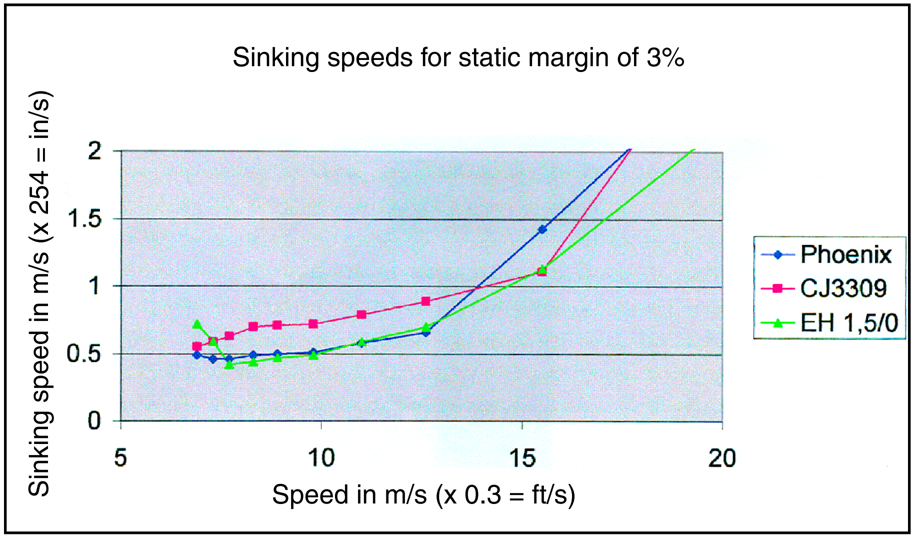
Figure 12: Sink polars for our model plank with a static margin of 3%

Comments:

With this lower static margin the EH 1.5/9 achieves a lower sink rate than all the other airfoils. Generally the range where low sinking speeds are achieved are broader.

Even the CJ-3309 has an acceptable sinking rate. That's probably why some people think it's a good thermal plank airfoil. But it doesn't get near the Phoenix or EH 1.5/9 airfoil.

The minimal sink rate for the Phoenix and the CJ-3309 occur at their lowest speed, which might be an advantage in thermal circles.



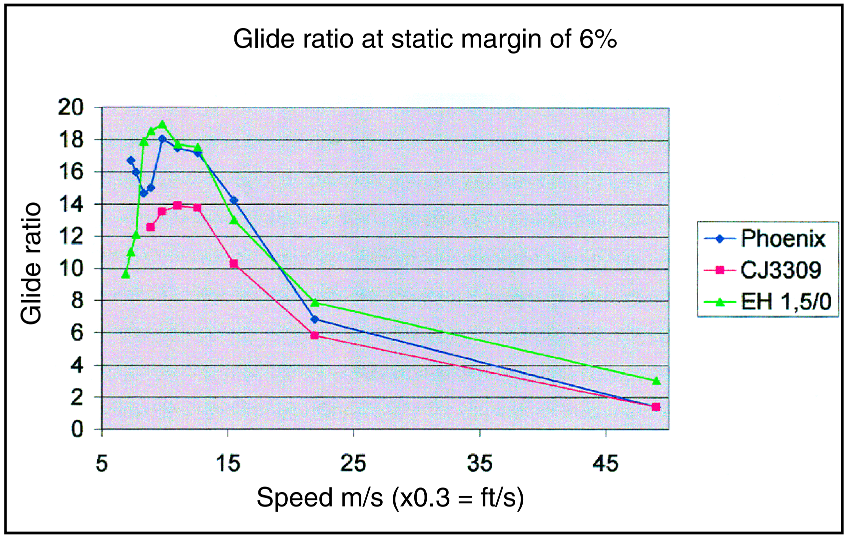


Figure 13: Glide ratios for our model plank with a static margin of 6%

Comments:

For the plank equipped with the CJ-3309 airfoil it was not possible to calculate the whole polar, because it was not possible to achieve the necessary positive pitching moments.

You should not focus too much on the fact that the polars do not look very smooth, it is because it was sometimes difficult to get the right pitching moments with the right flap deflections.

The CJ-3309 airfoil has no advantages at all and has a glide ratio that is 27% lower than the EH1.5/9 airfoil.

Above speeds of about 45 mph the EH 1.5/9 is better than all the others.

The Phoenix airfoil, even though it has almost double the camber, has no inferiority to the EH 1.5/9. Only at very low speeds it holds the good glide ratio a little bit longer.

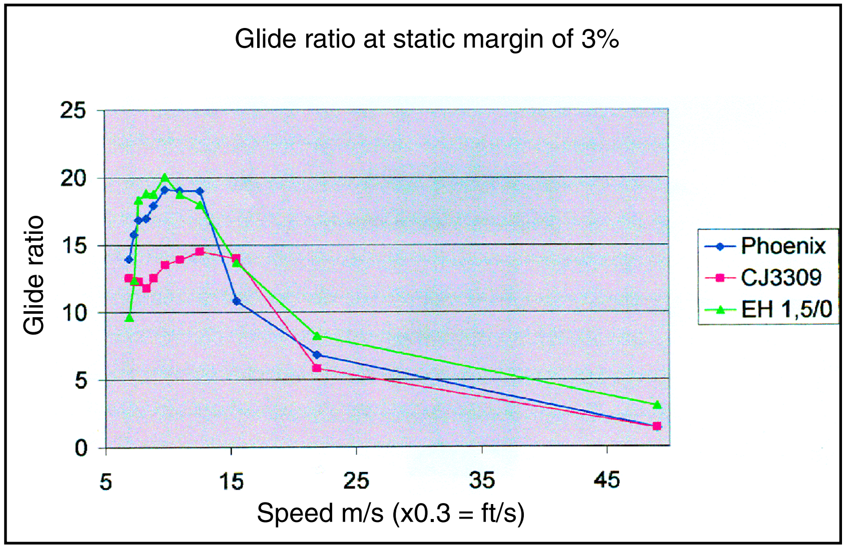


Figure 14: Glide ratios for our model plank with a static margin of 3%

Comments:

The CJ-3309 is still very "bad."

The maximum glide ratio for the EH 1.5/9 plank rises from 19 to 20 and the Phoenix gets closer to the EH 1.5/9 at low speeds, but pays at higher speeds with more drag, because of the necessary positive flap deflection which sets in earlier than with a static margin of 6% to achieve higher speeds. A hint in the direction that the camber is too high to get good all-round performance.

If it would be possible to change the CG in flight and thereby change the static margin, it would be beneficial for the Phoenix airfoil, but it wouldn't do much for the EH 1.5/9.

That's what you will expect. But I do think it is not a good way to look at what is happening.

With flying wings, you can not look at the airfoils alone, you have to take flap deflections and Reynolds number and laminar separation into consideration.

So I did the very hard work to calculate the gliding and sinking polars of these three models with XFoil for static margins of three and six percent.

Why hard work? Because I took into consideration the Reynolds number the plane is flying at, the moment coefficient which is necessary to achieve that flying speed or Reynolds number, and if the moment coefficient didn't correspond to the flight condition I added some flap deflection until the moment coefficient reached the necessary value at the right Reynolds number.

Furthermore I took the drag of the fin, which also depends on the Reynolds number, and 5% of elliptical lift distribution into consideration. The results and some comments can be seen in Figures 11 to 14.

I am pretty aware that the chosen airfoils are not state of the art, but my aim was to show something more general and I even think it's an advantage to compare airfoils that almost everybody has heard of or has even flown.

This article, one of a series, originally appeared in the German language magazine *Aufwind*.

RC Soaring Digest thanks the publishers of *Aufwind* for giving permission to reprint this series in English.

Information concerning establishing a subscription to *Aufwind* may be found at
<www.aufwind-magazin.de>
or by sending e-mail to
<bestellung@aufwind-magazin.de>

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

Claim number: 11801
Sub-class F5-P (Aeroplane, electric motor (non-rechargeable sources of current))
F5: Radio Controlled Flight Category
Type of record: N°181: Distance to goal and return
Course/location: Kiia (Estonia)
Performance: 19.92 km
Aeromodeller: Jüri LAIDNA (Estonia)
Date:19.07.2005
Previous record: 11.21 km (21.05.2005 - Gary B. FOGEL, USA)

Claim number: 11811
Sub-class F5-S (Aeroplane, electric motor (rechargeable sources of current))
F5: Radio Controlled Flight Category
Type of record: N°174: Distance to goal and return
Course/location: Nehatu - Vahastu and return (Estonia)
Performance: 80.43 km
Aeromodeller: Jüri LAIDNA (Estonia)
Date: 30.07.2005
Previous record: 68.9 km (06.11.2004 - Giorgio AZZALIN, USA)

FAI congratulates the Aeromodeller on his splendid achievements.

Harley Michaelis' *Genie* Series

Genie, Genie Pro, and *Genie LT/S*

Harley Michaelis, <harleym@bmi.net>

I do worry about the status and future of modeling with so few doing any designing or building and with so many succumbing to the notion that only the expensive ARF can perform well.

I lament that building skills are not being used or developed and that little is now being contributed back to the hobby in the way of construction articles that represent state-of-the-art airframes. The magazines that used to regularly accept my designs for construction articles no longer want them, claiming the ARF is what the public wants. They have "dumbed down" the content mostly to the level of the non-builder, beginning flyer. I worry that potential new modelers are being turned off by the high cost of the ARF.

My approach with the *Genie* line is to offer, at nominal cost, airframes as scratch building projects that compare in performance to the contemporary ARF. I show how to do things step by step in a very detailed web site that, with Jay Decker's generous help, I maintain as a public service to the builder-modeler. A liberal education in building beautiful and competitive composite airframes awaits anyone who just follows the instructions. I guess today's non-building modelers are intimidated by the thought of scratch-building high-performance birds, or wrongly believe it can't be done. The *Genie* line proves otherwise.

What's a *Genie*, *Genie Pro*, or *Genie LT/S*?

(All files referenced herein are available as downloadable PDFs from the *Genie* web site <http://genie.rchomepage.com/>)

The 145-1/2" span *Genie*, the 130" *Icon*-sized *Genie Pro* and the light and smaller version, the 10'-span *Genie LT/S*, comprise the *Genie* line of composite sailplanes.

These are likely the best documented, best supported, best built, most extensively tested, least costly state-of-the-art sailplanes on the planet, specifically designed for scratch building. They're do-it-yourself projects, but see the document "What's Available?" about plans, cores, composite fuselages, construction CD, and hardware pack. Using things available, modelers who've never even assembled a kit have built these airframes. See the Gallery file.

DOCUMENTATION: The various CD files take you through step-by-step with extensive text, drawings, and pictures. Along with the plans, this covers what's needed to independently proceed. Starting with File 1, information is provided in the order in which it is needed.

SUPPORT: An Index on the CD tells which files contain what. If you don't find what you need in the CD, write <harleym@bmi.net> for help. He'll either explain or point you to where it's addressed.

BEST BUILT: With their many unique features and innovations, nothing is built like these ships. There's no skimping to cut costs. There are no commercially motivated short cuts to rush the work. However, all building techniques used are worked out to minimize the time needed to get superbly built, fine-performing and eye-catching airframes.

EXTENSIVELY TESTED: The larger *Genie*, of which 28 have been built by Harley for personal use, has been continuously refined in both design and engineering for over 12 years. The *Genie Pro* and the *LT/S* employ the same well-proven features.

Starting with the *Atrix* design (Dec.'86 *MA*) Harley has built over 60 personal airframes of this type with 3-piece saddle-mounted wings. They've been progressively refined to be simpler, stronger, more sophisticated, more efficient, more durable, and more eye pleasing.

LEAST COSTLY: See File 5. You'd be hard pressed to get $300 into these airframes even using Les's fine, CNC cut cores. Yet, one is equal to or better in all-around performance than fully carbon-skinned ARFs costing $1,500 or more. Available composite fuses (File 7) add about $100 to costs.

UNIQUE FEATURES AND INNOVATIONS: There are dozens, including the following:

Slim, curvy fuselages/fins are either assembled from ply, balsa and CF, then shaped, glassed-over, and painted, or available in composite form. The fuselage in the photo on the next page is the larger *Genie/Genie Pro* composite fuselage.

All feature a droop snoot and bowed boom low profile that allows nose-first landings without spearing, and contributes to overall airframe drag reduction.

Even the glassed-over fuselages are light, but not flimsy or delicate. They take a "gorilla" grip behind or under the wing for high-tension launches and take a pounding on landing. They are resilient, and with the light tail, the dorsal, low stab, and CF laminate between doublers by the fin, are not prone to breaking by the fin in hard landings. If they break in an extreme situation, it's possible to restore them to original appearance. See the file "Anatomy of a Fuselage Repair".

The droop snoot puts the nose down first without spearing, helps avoid damage to

flap servos if flaps are down on landing, and contributes to smooth overall airflow. Mike Selig determined that the droop snoot, bowed boom combination, as used in his *Opus* design, results in a 30% reduction in overall airframe drag. The extraordinary quietness of these airframes is testimony to their overall cleanliness.

Internal rubber grippers firmly secure stabs (1 oz. for the pair) for flight on the solidly fixed, non-rotating main pivot wire. The tubes in the stabs freely rotate on the fixed wire. Rudder (1/4 oz.) is knuckle-hinged and detachable. Stabs and rudder are inexpensive, simple, practical, efficient, built-up, repairable Monokoted structures. Stab position avoids blanking out from the wing wash and stays effective at low landing speed.

A molded canopy shell for use with the glassed-over fuse is in Harley's package of hardware. Composite fuses come with their own canopies. The same simple, clean internal system is used to stabilize and retain them. See File 1 and page 7 of File 7.

A key to fine performance is an efficient and strong wing. The quad-taper planforms developed provide essentially elliptical lift distribution. A blend of Selig airfoils assures favorable characteristics in all ways important to thermal competition.

There is a rectangular, Kevlar-wrapped, CF-center spar system which, along with the dense foam core and the overall carbon skin, yields a wing that handles those high-stress, pedal-to-the-metal, deep-dip-and-zoom launches with impunity. The lightweight LT/S will do especially spectacular launches on winches typically used for traditional thermal contests.

Glass and CF cloth go directly over the cores. The Mylar carriers are pre-painted to yield a beautiful, near-fine finished wing as it comes out of the bag. Fine-finishing the LE to a glass-smooth, pit-free, glossy painted finish, as detailed in the Fine Finishing file, is unique to these scratch-built airframes. The overall appearance can rival that of molded wings, including those with 2-tone or even 3-tone LE's.

The *Genie* line of airframes is the only one that readily and conveniently accommodates the installation of the ultra-slick, all-internal Rotary Driver System explained in File 6. Wings are totally clean. Protruding horns, clevises, threaded rods, and bumpy covers are eliminated. Nothing hangs out to create parasitic drag, cause noise, or catch on things.

Other high performance, contemporary airframes made with squared-up servo wells either hamper or totally defeat doing a proper RDS installation.

Using the RDS, all wing servos can be mounted in the center section. No connectors or leads extend into the tips. These and the absence of outboard hardware help keep mass inboard for agility in the turn axis.

Light, simple aileron-operating mechanics are automatically linked as tips are attached and automatically disengage if a tip gets knocked loose in a dork.

In the tip sections, the overall unidirectional CF cloth used in the layup over the recommended Dow High Load 60 cores provides great strength with a combination of skin stressing and core resistance to compression. No spars are needed there since, using the RDS, no structure-weakening openings for servos need to be made.

Beautiful and precise CNC cut cores, made from the Dow High Load 60 foam, are commercially available for all three ships. See the "What's Available?" file.

Flex is present in the wings of Burt Rutan's unique and efficient designs, in the very high aspect ratio, full-scale carbon sailplane wings, and also in wings of soaring birds.

All of Genie line wings provide an element of this aeroelasticity by use of lightweight, blue tempered, clockspring steel blades (in Harley's hardware package) for tip section attach and support.

The compact boxes for these thin blades are simple, lightweight, sturdy, and securely imbedded between Kevlar wrapped spars and other CF reinforcement.

Aeroelasticity has a 3-fold purpose here.

(1) Something can give without breaking, for example, when a ship ends up inverted on a landing and flops hard on one or both tips.

(2) Blade flex during launch helps relieve stresses that could cause compression fractures in the top skin. No such fractures have ever been observed in the tips or center section, top or bottom.

(3) On abrupt tow release from a high-tension launch in which blades are flexed, the tips do a down stroke to provide an impetus into the zoom. This is observed in what appears as a leaping action in a well-timed release.

The simple, ply laminations towhook block system has holes spaced on 1/4" centers, but another adjustment is in the amount of towhook shank exposed. Extending a towhook has a similar effect as moving it back. The combination makes very fine adjustment possible, for optimum tow.

Common half-inch-thick servos ,such as the JR micros, Volz, Airtronics 94761Z, and Hitec, all work very well in the wings. The side mounting lugs on super-thin "wing servos" are an obstacle to proper mounting of flap servos for the RDS. Harley's Easy Mounting System (HEMS), detailed in File 3 is a simple, inexpensive, easily-fabricated mounting system for the RDS. No mounting lugs are needed.

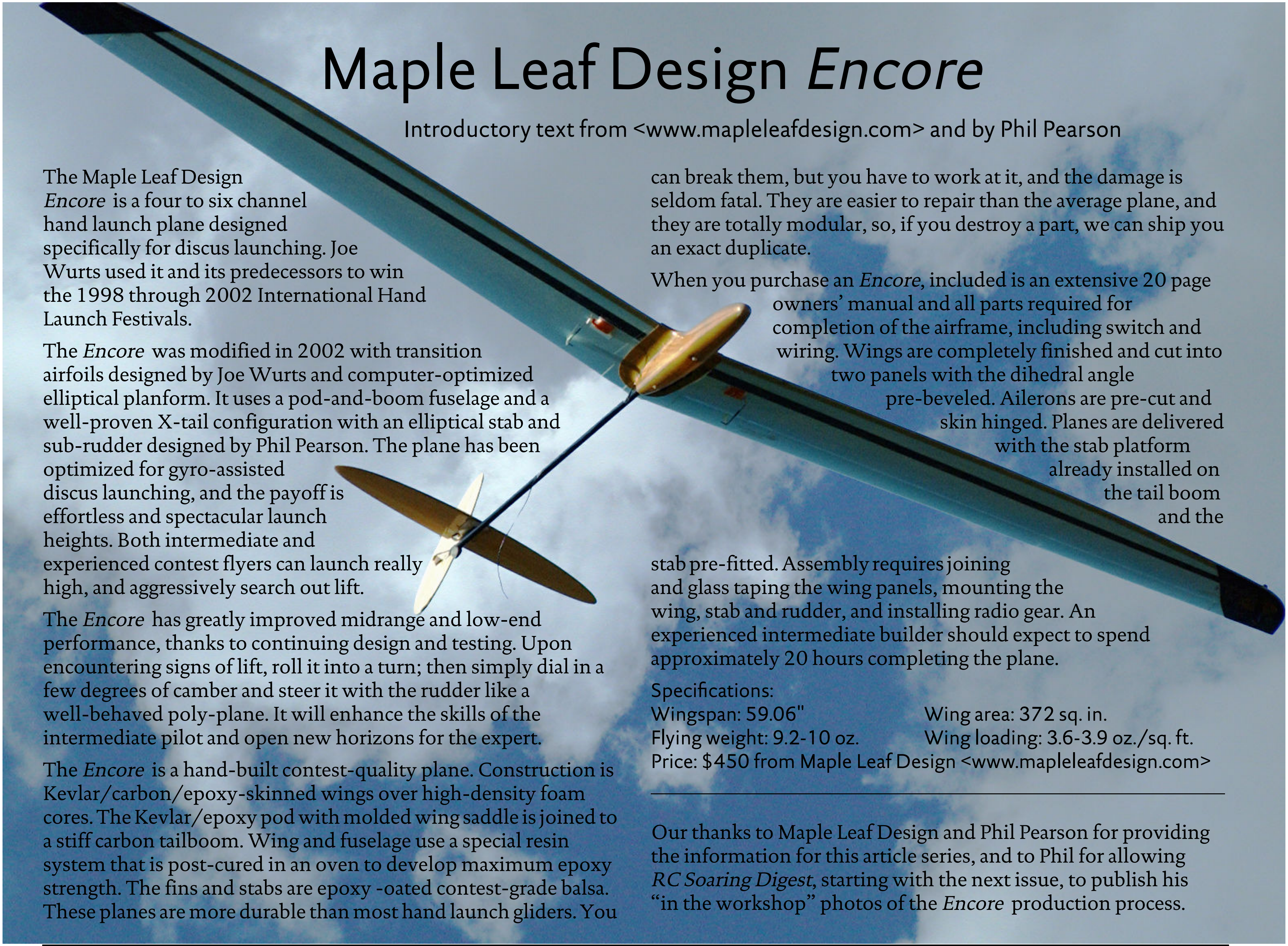
Building just one of the ships in the *Genie* line, compared to buying a contemporary molded, all- carbon wing ARF, can save you $1,000 or more.

With that you can get set up for life with the tools and equipment to make your own beautiful airframes.

You'll then have something to take real pride in, and you can work independently of others for repairs, replacements and costs.

As we're finalizing this issue, Harley has started his own *Genie* #29, and Chris Boultinghouse has committed to documenting the construction of his *Genie*, complete with photographs of the various stages of the building process.

We're looking forward to publishing this information within the pages of future issues of *RC Soaring Digest*, and hope readers are as well.



Maple Leaf Design *Encore*

Introductory text from <www.mapleleafdesign.com> and by Phil Pearson

The Maple Leaf Design *Encore* is a four to six channel hand launch plane designed specifically for discus launching. Joe Wurts used it and its predecessors to win the 1998 through 2002 International Hand Launch Festivals.

The *Encore* was modified in 2002 with transition airfoils designed by Joe Wurts and computer-optimized elliptical planform. It uses a pod-and-boom fuselage and a well-proven X-tail configuration with an elliptical stab and sub-rudder designed by Phil Pearson. The plane has been optimized for gyro-assisted discus launching, and the payoff is effortless and spectacular launch heights. Both intermediate and experienced contest flyers can launch really high, and aggressively search out lift.

The *Encore* has greatly improved midrange and low-end performance, thanks to continuing design and testing. Upon encountering signs of lift, roll it into a turn; then simply dial in a few degrees of camber and steer it with the rudder like a well-behaved poly-plane. It will enhance the skills of the intermediate pilot and open new horizons for the expert.

The *Encore* is a hand-built contest-quality plane. Construction is Kevlar/carbon/epoxy-skinned wings over high-density foam cores. The Kevlar/epoxy pod with molded wing saddle is joined to a stiff carbon tailboom. Wing and fuselage use a special resin system that is post-cured in an oven to develop maximum epoxy strength. The fins and stabs are epoxy -oated contest-grade balsa. These planes are more durable than most hand launch gliders. You can break them, but you have to work at it, and the damage is seldom fatal. They are easier to repair than the average plane, and they are totally modular, so, if you destroy a part, we can ship you an exact duplicate.

When you purchase an *Encore*, included is an extensive 20 page owners' manual and all parts required for completion of the airframe, including switch and wiring. Wings are completely finished and cut into two panels with the dihedral angle pre-beveled. Ailerons are pre-cut and skin hinged. Planes are delivered with the stab platform already installed on the tail boom and the stab pre-fitted. Assembly requires joining and glass taping the wing panels, mounting the wing, stab and rudder, and installing radio gear. An experienced intermediate builder should expect to spend approximately 20 hours completing the plane.

Specifications:

Wingspan: 59.06"	Wing area: 372 sq. in.
Flying weight: 9.2-10 oz.	Wing loading: 3.6-3.9 oz./sq. ft.

Price: $450 from Maple Leaf Design <www.mapleleafdesign.com>

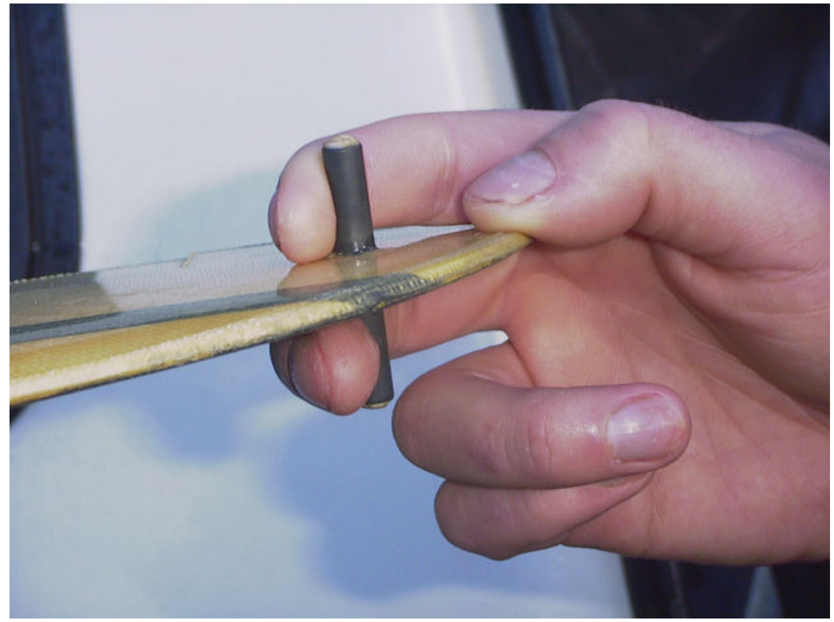
Our thanks to Maple Leaf Design and Phil Pearson for providing the information for this article series, and to Phil for allowing *RC Soaring Digest*, starting with the next issue, to publish his "in the workshop" photos of the *Encore* production process.

Opposite page: A classic *Encore* against cumulus clouds. This is a composite photo; *Encore* photo by David Beardsley, background clouds and sky photo by Phil Pearson.

Above: *Tactical Err* side-launch designed by Harold Locke. Harold is the originator of the side-launch technique (Seattle area). Model built by Phil Pearson. The first side-launch was flown by Phil Pearson at IHLGF in 1997.

Upper right: On the left, with Kevlar pod, is Phil Pearson's *Meteor*. On the right, Harold Locke's scratch-built prototype side-arm launched HLG, predecessor to the *Little Nipper,* circa 1999.

Right: Harold Locke with *Experimental Poly,* controlled in roll axis with wing mounted spoilers. A servo activates a pull string to activate one spoiler up, rubber-band return. Very effective for roll control, but not competitive in light air due to additional drag.

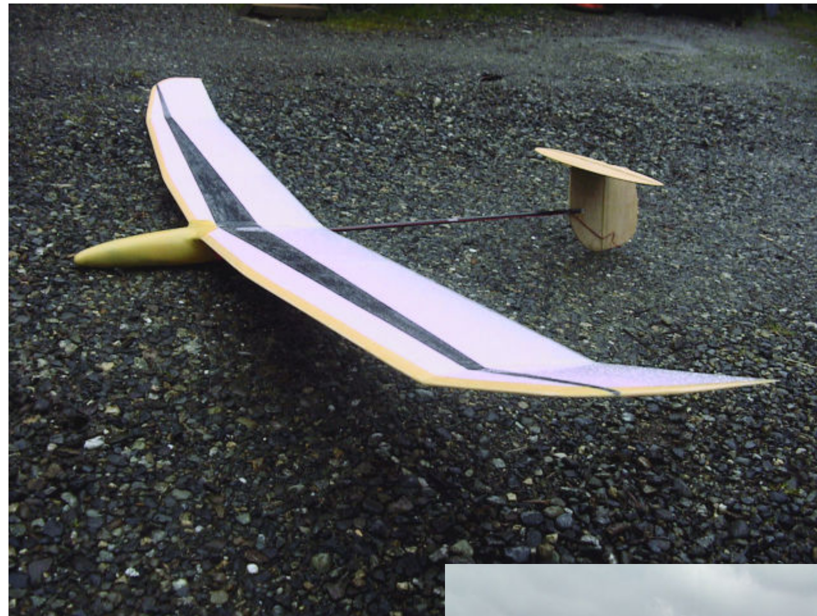


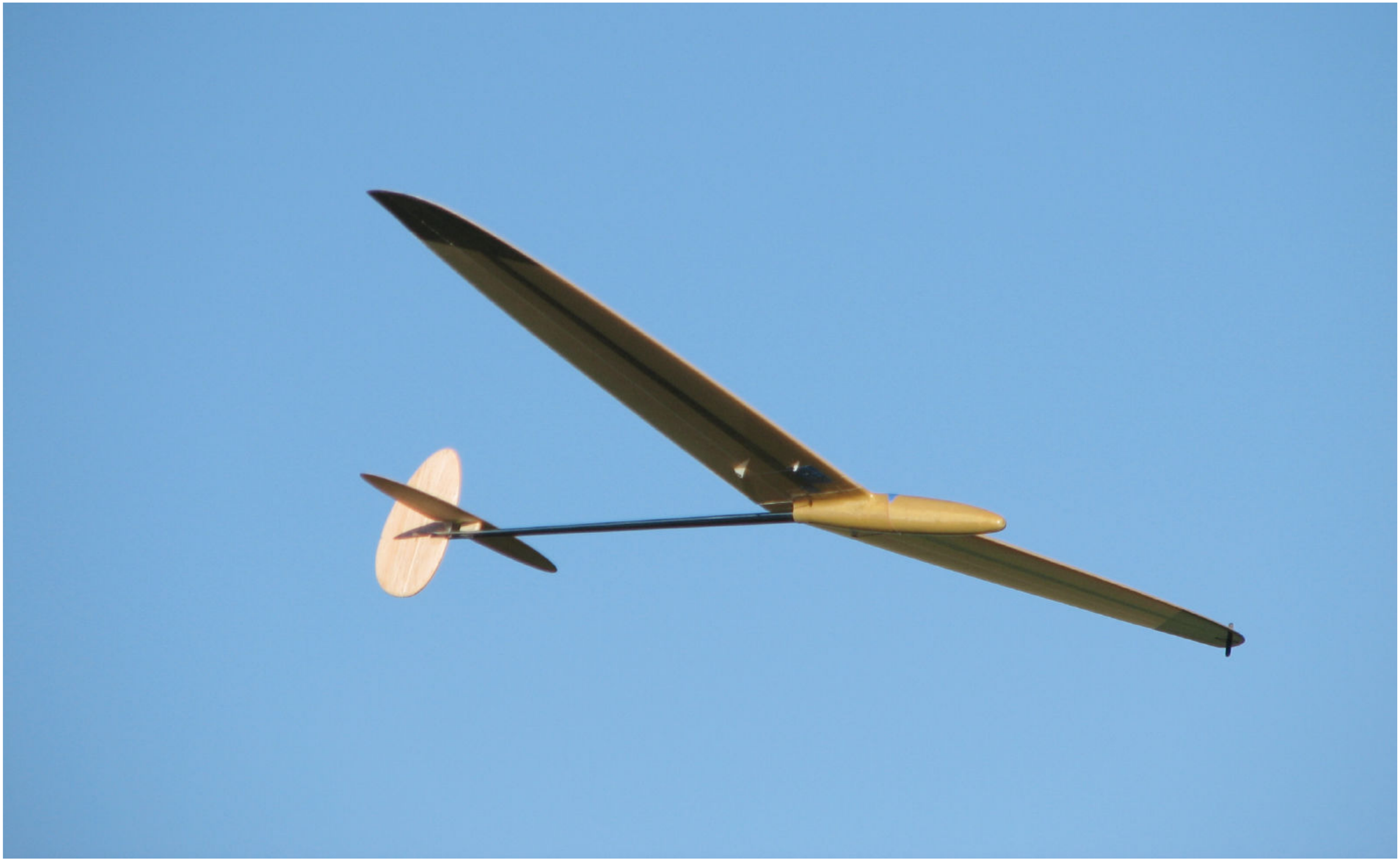
Above: Dick Barker and *Uplink* at SASS contest, circa 2002. Dick contributed 360 degree discus launch, enabling full 1.5-meter-span planes to be thrown by side-launch technique.

Upper right: Throwing peg in wing. This was a German contribution to discus launch. Prior planes were thrown by pinching the wing between thumb and fingers, so they tended to slip out of sweaty contest hands.

Right: Early morning light thermal/slope flying at Glider Hill, Coyote Hills state park, South San Francisco Bay, California. T-tailed *Encores* with poly prototype, circa 2000.

Light wind/thermal soaring over logged-off land, Cole Gap, Cascades Mountains, Eastern Washington. *Encore* flown by Phil Pearson. Photo by Adam Weston. Inset: SASS contest 60 Acres, Redmond, Washington, September 2001





Opposite page: *Far left:* Adam Weston and early *Encores* at IHLGF Poway, California, 2002. *Upper*: Prototype poly with T-tail, circa 2000. *Far right*: Joe Wurts with six-servo *Encore* at IHLGF, Poway, California, 2005. Planform designed by Joe. *Lower:* Early over-hand-launch *Encore* with Kevlar fuselage, circa 1999.

Above: Ole Kanestrom's *Encore* during a trim flight, 2005

Schleicher Ka 8B N8740R

Photos by Mark Nankivil, <nankivil@covad.net>

The Schleicher Ka 8B is a single-seat trainer version of the Ka 7 two-seater. Its construction is based on the Ka 7, but the design is derived from the Ka 6. Because of its good flying characteristics and ability to work weak lift, it's ideal for club use.

The fuselage is of welded steel tubing with spruce longerons and covered with fabric. There's a fiberglass nose cone. The wings have a single spar with a plywood leading edge D-tube, and fabric covering aft of the spar. Schempp-Hirth airbrakes are on both upper and lower wing surfaces. The tail assembly consists of plywood-covered wooden frames, control surfaces are fabric covered. A fixed single landing wheel, with brake, is fitted along with a skid, and there is a steel spur at the rear of the fuselage

More than 1,100 Ka 8s of all versions have been built. The structure lends itself well to amateur construction, and is an excellent choice for the scale sailplane modeler. We were very impressed with the color scheme and overall of this Ka 8B, and felt the 'ship needed be documented for *RCSD* readers.

This walk-around was photographed by Mark Nankivil at the Wabash Valley Soaring Association 2005 Vintage/Classic Glider Regatta, at Lawrenceville, Illinois. This Ka 8B was manufactured in 1963, carries serial number 8189, and is owned by the Wabash Valley Soaring Association, Lawrenceville, Illinois.

Schleicher Ka 8B

Designer	Rudolph Kaiser
First flight	November 1957
Wing span	15.0 m (49 ft 2.5 in)
Length	7.0 m (22 ft 11.5 in)
Height	1.57 m (5 ft 1.75 in)
Wing area	14.15 m^2 (152.3 ft^2)
Wing section	Göttingen 532/533
Aspect ratio	15.9
Empty weigh	190 kg (419 lbs)
Maximum weight	310 kg (682 lbs)
Water ballast	none
Maximum wing loading	21.9 kg/m2 (4.48 lbs/ft2)
Maximum speed	200 km/h (108 kt)
Stalling speed	54 km/h (29 kt)
Maximum sinking speed	0.65 m (2.1 ft)/sec @ 60 km/h (32.5 kt)
Maximum rough air speed	130 km/h (70 kt)
Best glide ratio	27 @ 73 km/h (39.5 kt)

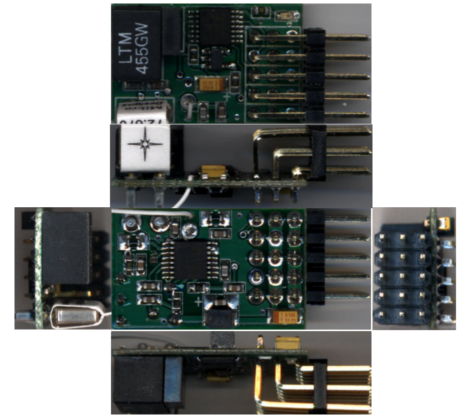

N8740R


9-27

Mikro Designs

Mikro SPF-5-RXO

5 Channel Receiver



The name Don McGlauflin may not be readily recognizable, but mention the Sirius Charge Pro, or the Sirius SuperTest, and you'll most likely hear, "Oh, yeah!" Don is no longer making the Sirius line of charging equipment (the line has been taken over by George Joy/Peak Electronics), but he recently reentered the electronics market with some interesting RC components.

We consider the Mikro SPF-5-RXO five-channel receiver to be the headliner of the Mikro Designs offerings.

Briefly, the SPF-5-RXO is a digital receiver of incredibly small size which exhibits quite exceptional performance and has a number of programmable features. And it has end pins!

Let's start with the physical dimensions. That image at the upper right of this page is a full size rendition of this receiver. The circuit board is 1.00" long and just 0.65" wide. With crystal in place, the overall height is 0.40". Weight? With antenna, crystal, and paper "case," it's just over five grams. The antenna weighs about a half gram, as does the paper case, so the basic receiver is just four grams.

The receiver utilizes what Mikro Designs calls a "digital signal analysis system." While considered single conversion, we found its performance on the bench matches that of our Hitec and FMA Direct dual conversion receivers. Field reports indicate it's extremely resistant to adjacent channel interference, as well as electrical and mechanical noise.

The programmable functions are both varied and tremendously useful.

- The SPF-5-RXO comes set up for negative shift transmitters. To set it up for JR transmitters, simply use the included jumper to short the Aileron Signal and Battery pins, plug in the battery, move the jumper from Aileron to Elevator, then unplug the battery. Remove the jumper. Done. Airtronics and Multiplex transmitters are handled in similar but not identical fashion. A small green LED blinks to confirm the setting.
- The SPF-5-RXO can be set up to cover channels 1-5 or channels 1-4 and 6. The latter is used by some transmitters for independent ailerons.
- The SPF-5-RXO can also be programmed for elevon mixing.

Channel 5/6 and elevon mixing on/off are programmed at the same time by placing the jumper on the Elevator pins and adjusting the transmitter throttle stick. There are four possible settings (5/off, 5/on, 6/off, 6/on), and once again the green LED confirms the setting.

The green LED serves an additional purpose as well. If the receiver does not detect a transmitter signal, the light glows. It turns off once it detects a signal. Cool.

Since the SPF-5-RXO is software driven, upgrades can be made depending on field experience. The SPF-5-RXO software is currently in Revision 2, and the receiver is now compatible with the Futaba 6EX and other short-frame transmitters.

A few other positive comments about the SPF-5-RXO...

Because the SPF-5-RXO is designed to operate where a small lightweight receiver is desired, the battery complement can be anything that produces 2.5 to 6.0 volts. This makes it ideal for small aircraft where a single lithium cell is desired.

While we were writing this review, Don sent us an e-mail message with the following additional information:

"* Over one mile range in the air. (This required two pilots with cell phones. What a flight!)

"* 100% adjacent channel rejection. (Tested by turning ON a channel 46 transmitter right next to an SPF-5 with channel 45 crystal. NO bleed over!)

"* Polite shutdown during long noise bursts or total loss of signal: simply stops sending servo pulses.

"* Very little glitching with weak signals. SPF-5 flywheels through short noise bursts (two frames or less).

"* Will not send ANY servo pulses on power-up until good transmitter signal is acquired. (Yes, you may SAFELY turn on the SPF-5 first!)"

One of the options for this receiver is the use of a short lightweight base-loaded antenna ($9.95). This can be installed by Mikro Designs before shipping to you, or you can install it yourself if you're not squeamish about soldering in confined spaces. In our ground range test with an antennaless transmitter, there was no difference in performance between the standard 39 inch antenna and the base loaded antenna. Both gave glitch-free servo control to over 150 feet.

	Mikro SPF-5-RXO	Receiver A
Size	1.0" x 0.6" x 0.4" horizontal (end) pins	1.30" x 0.80" x 0.58" vertical pins
Weight	5.1 grams	9.0 grams
Design	single conversion, digital signal analysis	dual conversion, super-heterodyne
Channels	1 - 5 or 1 - 4 and 6	1 - 5
Modulation	FM/PPM	FM/PPM
Ultimate bandpass	±9 KHz	±8.5 KHz @ >55dB down
Usable sensitivity	-103 dBm	>-95 dBm
Failsafe	None	Last good frame
Voltage	2.5 to 6V DC	3.5 to 16V DC

Before we forget, the price of the SPF-5-RXO is only $43.95, and under $50 with a Mikro Designs crystal.

As you can no doubt tell, we are extremely pleased with the SPF-5-RXO. Our two will find homes in one of our *Alula* SAL HLGs, and another RC-HLG we're planning to build.

In addition to the SPF-5-RXO, Mikro Designs puts out the same receiver with a 20 Amp brushed motor ESC in the form of the SPF-5ESC, $53.95; a separate 20 Amp brushed motor ESC with adjustable cutoffs for 1, 2, 3 or 4 cell lithium packs, the Super GFS, $34.95; a super-small (1/3 gram) 4-Amp brushed-motor ESC, the Mikro GFS ($14.95-$18.95); and the SuperSwitch, a neat add-on circuit that will operate auxiliary functions — lights, motors, etc. — up to 18V and 20A, yet weighs just 1.1 grams ($29.95).

All Mikro Designs products are made in the USA.

Good going, Don! Thanks!

Duo-Dart Construction Notes

by Steve Skloss

I finally got a chance over the Thanksgiving 2005 holiday to finish up and maiden my electrified "Blackbird-ish" model. I call it the *Duo-Dart*.

"Duo" stems from the fact that it can be flown either as an e-plane or sailplane simply by changing the fuselage section. "Dart" because it's a rather small, agile bird. The tail fin is mounted to the wing and the servos and receiver are mounted in the wing also. One fuselage section (I call them "shoes") contains the motor, ESC and Li-Po battery, while the other simply contains a 110mAh receiver battery for gliding (while the Li-Po charges). Specifications upon completion:

Wingspan: 36"
Wing Area: 261in^2
Airfoil: BW-05-02-09
Washout: -1.0 degree at tips
Root Chord: 9.5"
Tip Chord: 5"
Leading Edge Sweep: 4"
Motor: Graupner Race 280
Prop: Graupner CAM 4.7 X 2.4 folding
Battery: 2 Cell Tanic 830mAh Li-Po
AUW (powered): about 8.5 oz.
Wing Loading (powered): 4.7 oz/ft^2

Initial test flying was rather interesting. I believe the model was somewhat nose-heavy, as it liked to "hunt" in the pitch axis with ANY change in speed. Also, there was a tendency to "tighten up" in thermal turns.

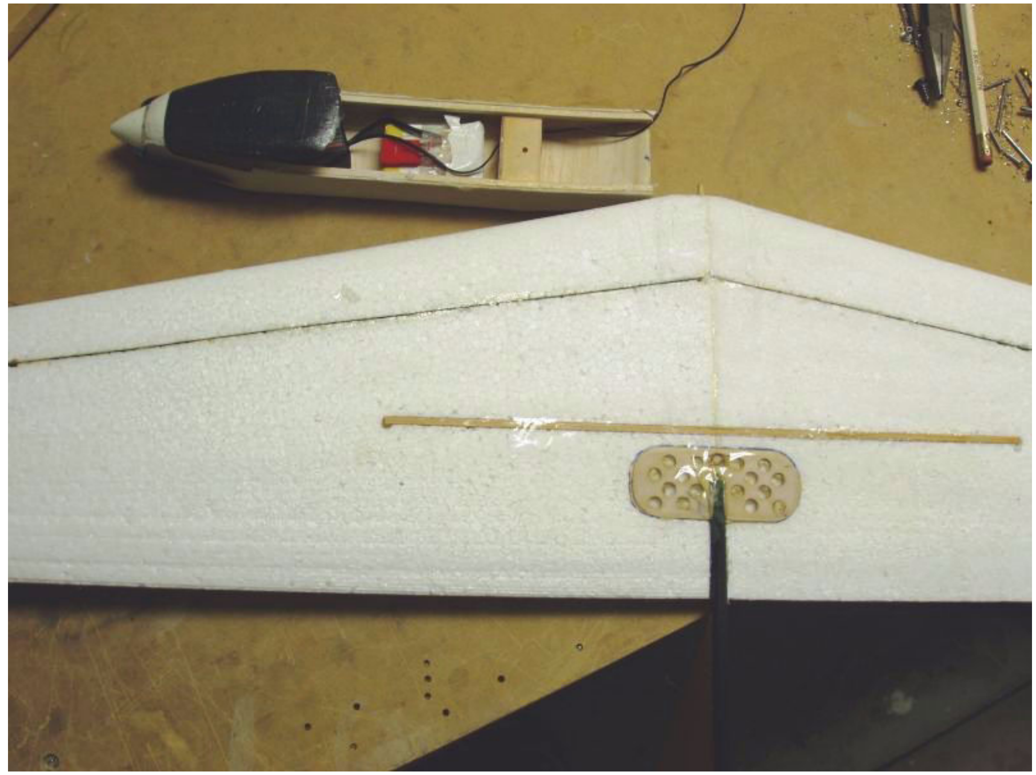
At that time it was balanced at 3.25" from the nose at the root. The dive test ended rather rapidly as it pulled out quickly. With power on, she wanted to climb, but I tamed that with some down thrust and mixing in down elevon with throttle. The programmed throttle/elevon mix helps the climb somewhat as it reduces drag by taking out some of the reflex. Only problem is that less down elevon is needed as the battery loses power, and I have to compensate with manual up elevon or turning off the mix.

The pitch problem was eventually resolved with motor down-thrust of about -3 degrees. The tendency to "tighten up" in thermal turns turned out to be due to unequal control throws.

I did rebalance to about a 3% stability margin with great improvement in gliding and low speed handling. Elevon mix was changed to 60%-40% aileron-elevator to help control pitch, now very sensitive. Once these "opportunities" were taken care of, she became much more pleasurable to fly. On a decent thermal day I could fly for an hour or two.

Then Christmas came...

For Christmas, I received an AXI 2212/26 motor and controller. Who am I to just let it sit in a box? Out came the chop saw and, with a quick pass, the nose was shortened just enough to allow the brushless motor to fit. Fitted with a 9x5 non-folding prop and rebalanced, the AUW increased from 8.75oz to 10.5oz adding about 1oz/sq ft to the wing loading. This put too much weight into the fore and aft extremes and killed its low speed handling due to increased drag from the elevons, now using larger throws to swing the outward weight around. Also, the non-folding prop and large flat firewall, with no spinner, added even more drag, so gliding performance fell. Having a prop diameter that is one quarter of the wingspan created some fun torque gyrations, as well.



Wing and electrified fuselage separated, showing mounting method.

Recommendations for next time? Add 3 to 4 degrees of dihedral, keep the speed 280 power system, or something equally light, and use outboard, large chord, elevons.

I do like the airfoil quite a bit. It seems to have less drag than the EMX-07 I am used to, and it is SILENT on a high-speed, low level pass!

Fuselage

The fuselage sides are cut from $^1/_{16}$" contest grade balsa and fully sheeted inside with $^1/_{64}$" ply doublers. The top (except the wing saddle) and bottom edges are lined with $^1/_4$" triangle stock. The wing saddle is lined with $^1/_8$" x $^1/_8$" square stock. Formers and firewall are cut from $^1/_8$" lite-ply, as is the wing bolt plate glued inside the fuse. Top and bottom sheeting is cross-grain $^1/_8$" contest grade balsa. Once the fuselage is formed up (sides, formers and sheeting glued together), use a compound miter saw to set two degrees of right thrust and -3 degrees of down thrust. Glue the (slightly oversized) firewall to the front of the fuselage with epoxy or poly glue, then shape the entire fuselage.

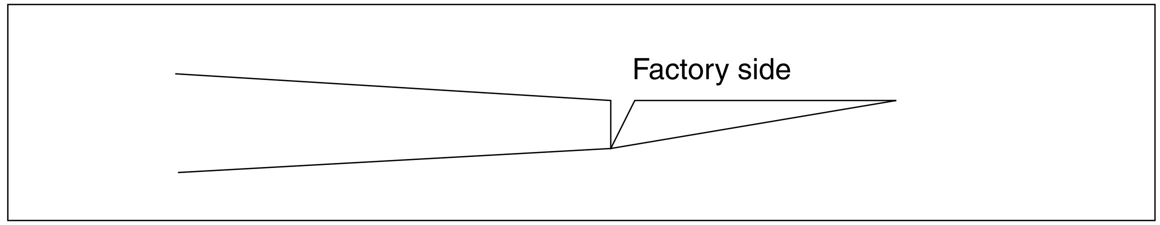
Apply a layer of 0.75oz/sq yd fiberglass to the outside of the fuselage with a heavy coat of Minwax Polycrylic. Not so much as to create runs, but heavy, as most of the Polycrylic is water and will evaporate off. Start on the bottom and wrap around the top. Hang to dry for a few days in a warm dry place. After a day or so you can handle the fuselage for fitting, but allow a week or so for full cure before flying.

Wing

The cores are cut from one pound virgin white foam. The main spar is $^{1}/_{8}$"x$^{1}/_{4}$"x10" spruce, slotted in using a Dremel with a router attachment and a $^{1}/_{8}$" router bit. The secondary spars are $^{3}/_{8}$" wide strips of 0.014" pre-cured carbon fiber sheet. Cut channels in the wing using a micro saw or Dremel with a fine engraving bit. Lightly coat the spars with poly glue and spray the spar channels with a fine mist of water. Insert the spars so that they are flush, and temporarily cover with packing tape so that the cores don't get glued to the beds. Place the cores in their beds and weight down to cure.

On top of the wing is a $^{1}/_{16}$" lite-ply wing bolt plate used to keep the bolt head from crushing the foam. Simply rout a pocket for it to fit flush, and glue it in with poly glue. The wing bolt is a 6-32 nylon bolt that shears quite well in a harder than normal landing, so buy four or five of them. The front of the wing is secured to the fuselage with a $^{1}/_{8}$" dowel that is glued into the root of the wing.

Cut the fin from a thick piece of meat tray foam – the guys at the grocery store will give you a couple for free. Sand a symmetrical airfoil shape into it and apply a layer of 0.75oz/sq yd fiberglass with Polycrylic. Glue the fin-boom (carbon arrow shaft) to the fin using poly glue. Cut the fin-boom plate from $^{1}/_{8}$" lite-ply and glue to the fin/fin-boom assembly, making sure that the fin is perpendicular. Trace the fin-boom plate onto the bottom of the wing (making sure it is straight) then rout out a pocket for it using a Dremel and router attachment. Glue the fin assembly to the wing with poly glue, set in cores, and let cure.



Paint the cores using water-based acrylic paints available from craft stores, or using left-over interior house paint. You don't need to create a gloss finish, as that will be supplied by the packing tape.

Tape Covering

Begin by spraying a light coat of spray adhesive on the top and bottom of the trailing edge, down the center of the bottom of the wing, and along the leading edges, and let it "flash" for about 15 minutes. Using fiberglass re-enforced packing tape, wrap a strip around the trailing edge. Apply a strip from tip to tip on the bottom of the wing, centering it over the main spar. Wrap a strip around each leading edge from root to tip. Finish covering the wing (bottom first) by applying another light mist of adhesive, let flash, and apply clear packing tape from trailing edge to leading edge with full width strips overlapping 1/8". Once top and bottom are complete, apply one final strip over the leading edges.

Elevons

Elevons are cut from $^{1}/_{8}$" contest grade balsa sheet and sanded to shape. Shape the elevons for a bottom hinge and so that the travel relief is beveled towards the "factory" side (see illustration above).

This allows the elevon to follow the original airfoil shape. Seal the elevons with two light coats of automotive lacquer. Cover the elevons with clear tape, leaving about $^{1}/_{4}$" at the leading edge for the tape hinge to cover. Hinge with clear office type tape (strong enough) top and bottom, then seal the ends of the elevons with thin CA.

Radio and Electronics Installation

Rout pockets on the top of the wing for the servos, and another for the receiver, Hold servos in place with tape. Place the receiver in the bottom of the wing just ahead of the tape covering the main spar ,and route the antenna through the fin-boom. Use $^{1}/_{2}$A control horns, mounting them on top of the elevons. Having equal throws is critical. The battery, motor, and ESC mount in the fuselage. Use an aileron extension to connect the receiver to the ESC. Leave room for the battery to be shifted for setting CG.

Balance and Flying

Balance the aircraft so that the CG is 3 $^1/_4$" from the leading edge at the root. To do so, make a balancing jig out of some scrap 2x4 and $^1/_8$" dowels with slightly rounded tips. Do not use your fingers to balance — on a flying plank, especially one this small, $^1/_{16}$" makes a world of difference. Set the elevon reflex so that the bottom of the elevon follows the curve of the bottom of the wing trailing edge.

First flights should be power off hand launches into a light breeze over tall grass. Once you feel confident that the CG is adequate and controls responsive, make a "power pulse" flight. By this I mean give it a strong hand launch slightly above the horizon, and once it's about 20 feet up, give it full throttle for about one or two seconds. If you notice that it wants to dive or climb dramatically, adjust up or down thrust accordingly.

Once you have the thrust line sorted, climb up to sufficient altitude and test the glide. If it sinks like a stone, try adjusting the CG back $^1/_{16}$" at a time until the power off glide improves. Remember that each time you move the CG back you will need to remove a little reflex as it will be more sensitive in pitch and want to climb. It will take a few flights to get the CG dialed in.

Optional Hand Launch/Up-start fuselage (Hence the "Duo")

Using the bottom wing core bed, cut out the center section to about 1 $^1/_4$" wide and glue a scrap piece of foam, about 2-3" long and the same width, to the front. Set the wing on the assembly and poke the wing bolt down into the foam to make a mark. Cut a piece of $^1/_8$" lite-ply about 1.5"x1.25" and recess it flush into the foam, centered over the bolt mark. Drill and tap the lite-ply for the wing bolt. With a piece of scrap $^1/_{64}$" ply about 1.25" square, drill a $^1/_8$" hole in the middle. Glue it to th e fuselage, centering it over where the wing dowel poked a hole in the foam block. Cut another piece of $^1/_8$" lite-ply 1"x1.5" and flush mount it to the bottom of the fuselage centered $^1/_4$" ahead of the determined CG. This is your up-start hook plate.

Rout $^1/_8$" slots, about 7" long and $^1/_4$" deep, down the sides, making sure it extends into the front block of foam about an inch or two. Glue $^1/_8$"x$^1/_4$" spruce or hard balsa stock into the slots. This creates longerons that lock the pieces of foam together and keeps you from crushing the foam when gripping it. Shape the foam fuselage to your liking, but leave room for your receiver battery.

Apply a layer of 0.75oz/sq yd fiberglass to the fuselage with Polycrylic and let dry for a day or two. Bolt the fuselage to the wing and, using a 110-270mAh receiver pack, find the battery location that rebalances at your determined CG. Dig out the foam from the fuselage at that location and drop in your battery. Now while your motor battery is charging, you can still fly with the birds! Enjoy!

The *Duo-Dart* as it is now, with AXI 2212/26 motor and controller. The original propeller is in front of the relatively huge non-folding 9x5 propeller. As the span is 36", the propeller diameter is now one quarter of the span! The change to brushless motor forced the weight up from 8.75 ounces to 10.5 ounces. The new motor also increased inertia in pitch, forcing greater elevator control throws.

Low-Speed Stability - Errata

Gregory Ciurpita, <g.ciurpita@flarion.com>

In a March 2004 article titled *Low-Speed Stability*, I discussed the three major moment forces affecting the longitudinal balance of an aircraft. The primary motivation for the previous article was to look at the longitudinal forces based on the C_m of the airfoil instead of the center of pressure. It also showed how airspeed becomes increasingly more sensitive to elevator trim setting as the CG is moved rearward.

Unfortunately, I incorrectly stated that "An aircraft can be stable at higher speeds but unstable at low speeds." While this statement may not be absolutely false, it certainly isn't true simply because the tail is producing a lifting force, as suggested in the article, nor was it the motivation for the article. I misinterpreted statements made by Simons[1] about lifting tail designs. What has become clearer after reading Etkin[2], is that like an airfoil, the entire aircraft has a moment coefficient, and how it changes with changes in pitch determines longitudinal stability.

$$C_m = C_{m0_w} + C_{L_w}(h - h_{n_w}) - V_H C_{L_t}$$

where C_{m0w} is the moment coefficient of the wing, C_{Lw} is the lift coefficient of the wing, h and h_{nw} are locations, as a percentage of the mean wing chord, respectively of the CG and the neutral point of the wing, V_H is the tail volume coefficient, and C_{Lt} is the lift coefficient of the tail.

One element being ignored in the above equation and the rest of this note is the moment caused by drag if the CG is sufficiently above or below the aerodynamic center of the wing. If the CG is below the aerodynamic center of the aircraft, drag produces a positive moment.

Since this equation is in terms of aerodynamic coefficients, it is independent of airspeed. However, it does depend on the angle of attack, α, which affects both the wing and tail lift coefficients, and it is the angle of attack, or pitch, that we wish to be stable. The following equation expresses the total aircraft moment in terms of α

$$C_m = C_{m0_w} + \alpha\left[a_w(h - h_{n_w}) - a_t V_H\left(1 - \frac{\partial\varepsilon}{\partial\alpha}\right)\right] + V_H a_t(\varepsilon_0 + i_t)$$

where a_w is the lift slope of the wing, a_t is the lift slope of the tail, i_t is the tail incidence angle, ε_0 is the downwash angle at the zero lift α, and $\partial\varepsilon / \partial\alpha$ represents the change in downwash angle as α changes[3]. In this equation, the tail angles, i_t and e_0, are positive when the leading edge is lower than the trailing edge.

This equation shows that the tail moment has two components: one that varies with α and one that depends on the elevator trim. The value of α affects the lift coefficients of both the wing and tail. The sum of the lift terms must equal the sum of the airfoil moment, C_{m0w}, and elevator trim.

For a specific elevator trim setting, there is one α where C_m is zero, where the aircraft is balanced. Changing the elevator trim changes the α that zeroes the aircraft moment. This α also determines the airspeed where the lift terms equal the weight of the aircraft. The following equation determines how much a change in α changes C_m above

$$C_{m\alpha} = \frac{\partial C_m}{\partial \alpha} = a_w\left[(h - h_{n_w}) - V_H \frac{a_t}{a_w}\left(1 - \frac{\partial \varepsilon}{\partial \alpha}\right)\right]$$

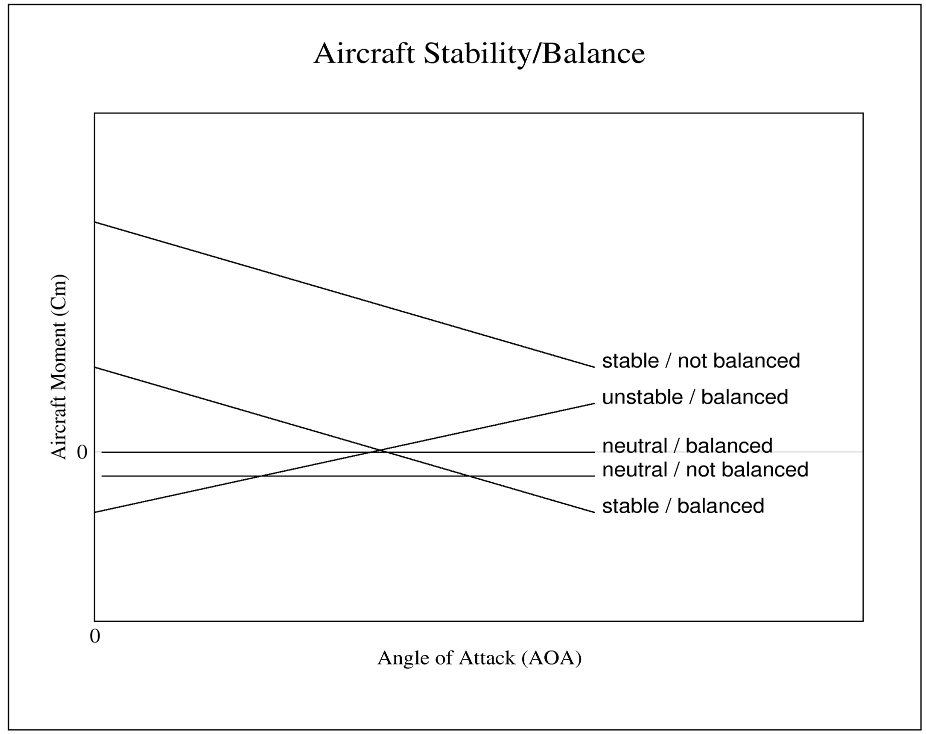
For a specific aircraft design, all the variables in this equation are constant. However, the CG location, h, can more easily be changed. If $C_{m\alpha}$ is a positive value, an increase in α makes the moment more positive, pushing the nose upward. If $C_{m\alpha}$ is negative, an increase in α decreases the moment force, pushing the nose downward. $C_{m\alpha}$ may also be zero, meaning a change in α has no affect on the moment force. A stable aircraft has a negative $C_{m\alpha}$, when turbulence causes α to increase, C_m becomes more negative to force the nose down.

The value of h can make $C_{m\alpha}$ positive, negative or zero. Increasing h, moving the CG rearward, increases the value of $C_{m\alpha}$. At some point the value of h makes $C_{m\alpha}$ zero. This is the neutral point of the aircraft, h_n, the CG location where a change in α has no affect on C_m. Locating h behind h_n will make $C_{m\alpha}$ positive, and locating h in front of h_n will make $C_{m\alpha}$ negative. The above equation can be rewritten to determine that value.

$$h_n = h_{n_w} + V_H \frac{a_t}{a_w}\left(1 - \frac{\partial \varepsilon}{\partial \alpha}\right)$$

Static stability requires that C_{ma} be negative, that the CG be in front of the neutral point, $h < h_n$. For an aircraft to be balanced, the value of C_m must be zero at some reasonable value of α. However, while an aircraft must be balanced, pilot preference determines the desired level of stability.

The included figure illustrates various possibilities of balance and stability. Changing the elevator trim shifts the curve up or down.



Both the stable and neutral but not-balanced cases simply require elevator trim adjustment to make them balanced.

At this point it should be clear that there is no one term in the equations above, such as a lifting tail, that cause instability. It is the aerodynamic design, the combination of elements, that determine stability, and stability is only one aspect of a design.

On a tailless aircraft, the equation for C_m contains no elevator terms.

$$C_m = C_{m0_w} + C_{L_w}(h - h_{n_w})$$

For a tailless aircraft, as for a conventional tailed aircraft, stability requires that the CG be in front of the neutral point. The aircraft neutral point is the same the wing's, $h_n = h_{nw}$. Again, h_n determines the CG location where a change in α has no affect on C_m, and this determine stability. In this case, if turbulence pushes the nose up, α increases, increasing C_L, and since the aerodynamic center of the wing is behind the CG, the increased lift pushes the nose back down.

To replace the elevator function, some mechanism is needed that affects C_{m0} and/or C_L. On tailless aircraft, rather than use the tail to counter balance the airfoil and lift moments, part or all of the wing's trailing edge is used to change the airfoil shape, affecting C_{m0} and C_L directly. The following equation describes the change of C_m in terms of the trailing edge deflection, δ,

$$C_{m\delta} = \frac{\partial C_{m0}}{\partial \delta} + C_{L\delta}(h - h_n)$$

where $\partial C_{m0} / \partial \delta$ is the change in the airfoil moment coefficient, and $C_{L\delta}$ is the change in the lift coefficient as the trailing edge is deflected.

If a downward adjustment of δ is considered positive, $\partial C_{m0} / \partial \delta$ is typically negative and C_{Ld} is positive. Adjusting δ downward makes the airfoil moment more negative, and shifts the lift curve upward, more positive. Inversely, adjusting δ upwards makes the airfoil moment more positive, and the lift coefficient more negative [4]. While the total affect changes in δ has on C_m is relatively small, the longitudinal moment of inertia of a tailless aircraft is smaller than a conventional aircraft, and less moment force is required to affect pitch control.

While these changes affect C_{m0} and C_L in opposite directions, a positive change in C_L causes a negative change in C_m because the CG is in front of the neutral point and h-h_n is negative. The negative of this difference, h -h, is the static margin. It is also the moment arm that determines how much the lift affects C_m.

Since C_L is typically always positive, it will always contribute to a negative C_m depending on the amount of static margin. This increases the need for an airfoil with a positive C_{m0}. While increasing the static margin increases stability, it also increases the affect C_L has on C_m.

On an unswept constant chord wing, the aerodynamic center at each span position is at the same longitudinal location. For a swept wing, the aerodynamic center of the entire wing is the mean of the centers of pressure across the entire span. Partial trailing edge adjustments, affecting the lift at different span positions, will shift the aerodynamic center of the wing.

If the lift is increased on the more rearward outer portions of a swept back wing, the aerodynamic center of the lift generated by the entire wing shifts closer (rearward) to the aerodynamic centers of those portions of the wing generating the increased lift. Conversely, if the outer portions of the wing produces less lift, the wing aerodynamic center shifts forward.

When the aerodynamic center moves rearward, away from the CG, the static margin remains the same, but the moment arm of the lift increases. This affects how much the lift affects C_m. Increasing the lift on the rearward portions will make C_m more negative, causing a nose-down pitch change.

1. *Model Aircraft Aerodynamics* 4th ed., Simons, Martin; Nexus Special Interests, 1999, pg 243.

2. *Dynamics of Flight: Stability and Control 2nd ed.*, Etkin, Bernard; John Wiley and Sons, New York, 1982.

3. Simons suggests that $\partial \varepsilon / \partial \alpha$ can be approximated by the value $35 a_w / A$, where A is the aspect ratio of the wing. Simons also indicates that the tail efficiency needs to be considered and suggests scaling the tail volume by 0.65 for a normal tail and 0.9 for a T-tail.

4. For the RG15 from the UIUC database, which has measurements for the RG15 at different flap settings, $\partial C_{m0} / \partial \delta$ is -0.0033, and C_{Ld} is 0.0215.