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Aero Modeller Annual 1978-79

AEROMODELLER ANNUAL 1978–79

A review of the year's aeromodelling throughout the world in theory and practice: together with useful data, and authoritative articles, produced by staff and contributors of the *AEROMODELLER*

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MODEL & ALLIED PUBLICATIONS
ARGUS BOOKS LIMITED
St. James Rd., Watford,
Herts, England
1978

AEROMODELLER ANNUAL

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acknowledges with thanks the undernoted sources representing a selection of the world's aeromodelling literature:

Australian Gliding	*Australia*
C/L Gazette	*U.S.A.*
F.A.I.	*Paris, France*
Flug + Modell Technik	*F.D.R.*
Model Airplane News	*U.S.A.*
Model Aviation	*U.S.A.*
Model Builder	*U.S.A.*
Modelar	*Czechoslovakia*
Modelarz	*Poland*
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N.F.F.S. Digest	*U.S.A.*
Radio Control Modeler	*U.S.A.*
Radio Control Technique	*Japan*
Star Skippers Newsletter	*U.S.A.*
Willamette Patter	*U.S.A.*

ISBN 0 85242 626 7

Printed in Great Britain by
BUTLER & TANNER LTD, FROME, SOMERSET

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INTRODUCTION

IN A YEAR when the Atlantic was conquered by helium balloon, when the Soviets refuelled their space vehicle Salyut 6 and changed crews as though it was a bus station, and when the American shuttle proved itself in free flight, one might expect parallel development in aeromodelling. There have been a few.

The Sitar brothers and supporting Austrian team have now met the contest challenge and shown how their fantastic speed glider is genuinely efficient enough to beat the best of the rest.

Duration records tumbled in the U.S.A. to Dick Weber. Almost sixteen hours in the air is an achievement for all concerned—including the engine, the batteries and the radio equipment.

We've seen the arrival of new British motors, both diesel and gloplug—hurrah! And the diesel has come back strongly as a sports engine. As forecast, the Old Timer movement has gained momentum and the vintage meets were very well supported this summer. Dads and sons seem to take well to the notion of putting radio in a Junior 60 or a Southerner kit model just for old times sake, and the real pleasure seekers have discovered that four stroke engines fly the big models like Eros, Mercury and Vulcan in a way that reeks of nostalgia. Now in the U.S.A. and to a lesser degree in the U.K., the BIG model emerges with attendant warnings from those who heed the restrictions of the law. When one flies a 25 lb model with up to 110 cc in front driving a 25 inch prop—its time to heed the regulations and equip oneself with authority to fly.

It's also the year for big meetings and they don't come any larger than that at Woodvale where the Control Line and Scale Champs were combined with a great spectacle involving funfairs, a custom car show and trade tent. The visitor may have been forgiven if he could not find the models.

It was a drenched Woodvale. The heavens opened to flood the hangar, the main tent and soaked the competitors. Unseasonally cold, it was enough to put off anyone used to warmer climates. But modellers are tough enough to withstand such hardships and made the most of it. Records were broken in Team Race by the incredibly fast Metkemeyer Brothers from Holland and the stunt team from the U.S.A. proved to be invincible. They now have three world champions and a runner-up in their 1978 line-up. Foam wings have "arrived" for these experts who have resisted the radio control construction for ages—even for veteran Bob Gieske's Nobler (though we noted he used the built-up and faded old model in the contest). Elsewhere, Woodvale gave us a World Champs in Combat with British finalists, a German and French victory in Speed, British wins in Scale and bitter disappointments.

Politics kept six nations away, and this spelled doom for the Control Line Scale event which had to be cancelled for lack of support. On the other hand an international free flight scale contest did materialise, albeit only between U.S.A. and U.K., but perhaps that is a start for the future.

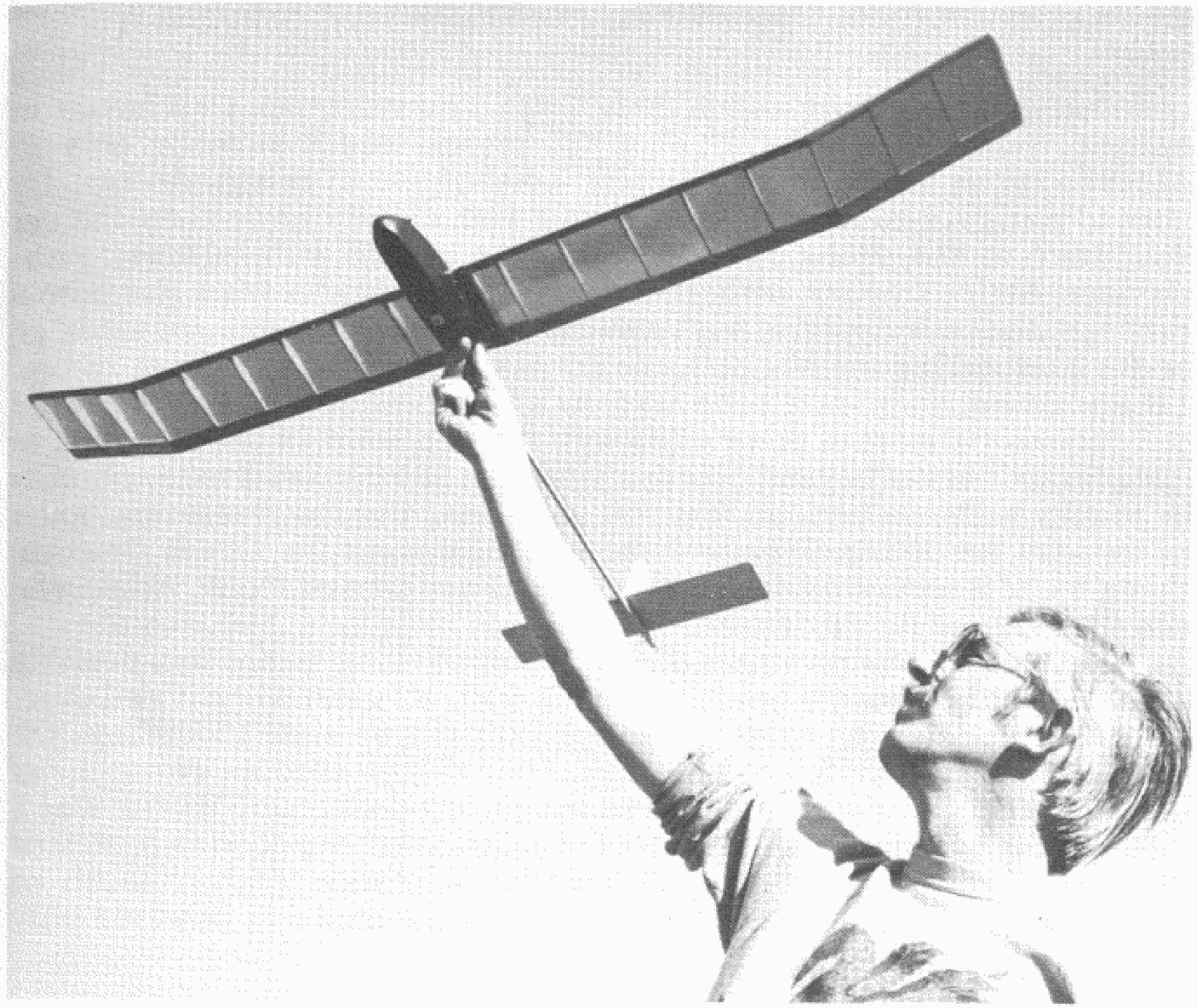
Small beginnings develop into long standing and important matters if they gain support and we feel that, like the original *Flying Aces* magazine, and the "Wakefield" Trophy, each of which were launched 50 years ago, there is a future for free flight scale.

The Woodvale Championships were oversize in all directions. To cover the costs of setting up for scale and control line, the gates were opened to remunerative ventures. Spectators could see a 200 m.p.h. pulse jet or a 20 ft. span 150 lb. Lancaster perform. The manufacturers put on display sessions and clubs made special models including Liverpool's big Boeing 747.

Consequently the organisation was stressed: but never more so than at a final dinner when over 1200 filled the Adelphi Hotel in chaos for a most untypical British finale. But only those who've tried to cope with this sort of situation have any grounds for comment.

Being in that position of a past organiser, we could see the problems clearly. They concern international modelling as a whole and have been the subject of long discussion in the F.A.I. It costs so much to organise any world championships that unless the fees are raised to share the burden, the organiser has to use enterprise—or obtain government support—to avoid financial disaster. The North West Area of the S.M.A.E. used their enterprise and we're pleased to say they are still solvent! Good luck to them and all modellers everywhere.

COVER
A Super Tigre G60 powers this big 69½ oz. "Atlantis" stunter by Marcos Beschizza of High Wycombe. His airbrush artwork, over the 800 sq. in. wing is a constant source of admiration. Moreover, thirty-two coats of Aero Gloss went into the surface to produce the super finish on a super model seen at the '78 Nats.



Author with Tadpole Mk 1—the ultra simple R/C glider. Photo: Kevin Flynn.

SPORT MODELLING

from the maestro of creative designers Jack W. Headley

WHEN THE Editor asked me to contribute a few words on sport flying, I had to think for some time before deciding just *what* to say. Ordinarily sport flying is something that's *done*, rather than being written about, like eating fish and chips. (Well actually I once did read an article in one of the glossier Sunday supplements about this, eating f. and c. that is.)

It was one of those reverse snobby things they put in occasionally, like wearing cloth caps. The real point of the piece was a discussion of the largest fish and chip emporium in the world, "Up North" somewhere. (This doesn't really count.)

Anyway I decided, after the aforementioned thinks, to begin by first writing a few words about what sport modelling and sport flying isn't, if you follow me. Maybe then it will become clearer what sport flying is all about.

One of the best things sport flying isn't is contest flying. Being a truly dedicated sport flyer automatically makes you a non-contest modeller—if you neglect the sport model contests that pop up now and again. (Sorry, Col. Bowden.)

The beauty of being a non-contest flyer is that it relieves you of having to be seen with all the latest contest type clobber.

You haven't to worry about what the latest design in circle tow hooks might be for next season, or having to explain to the Post Office that you need a money order for 47,368 Transylvanian Drachmas, in order to purchase that "Glögg" 3.5 cc motor, which is made only in Moravia by an independent Workers' cooperative of aeromodellists. Or how to put your new timer, which cost you slightly more than the car you drive to the flying field in, and operates the auto-rudder, auto-elevator, engine stopper, dethermaliser, and Lord knows what else, into a fuselage that no longer has any cross-section left. *Or . . . or. . . .* I *could* go on for ever, taking the Michael, the list is endless, and the target so big. I'll just do one more as it's the best. As a non-contest flyer you are saved the dubious pleasure of driving through the wee hours of the morning, to just past the back of beyond, where civilisation as we know it today permits us to play with our toys, so that you can spend the few remaining hours of the day *not* flying. I believe the technical term for this is "tactical flying", and it seems to be the essence of current contest flying, to see who can actually *not* fly the longest.

Somehow the pleasures of all this sort of thing escape me, possibly it's akin to banging one's head against the wall, it's great when it's all over.

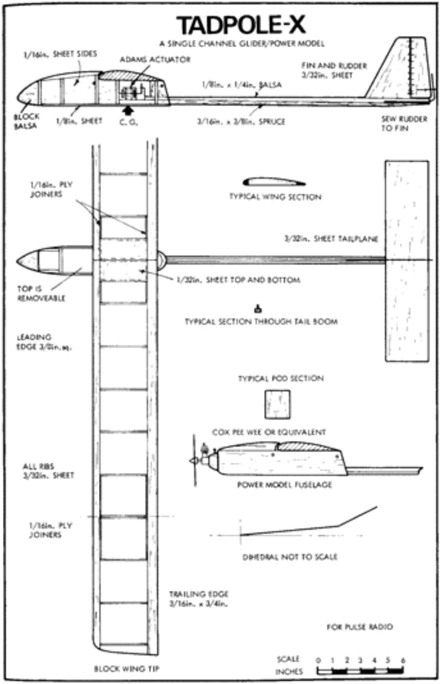
The next thing sport modelling isn't is true scale modelling. Oh what a grim subject this is. All those worrisome details—research *ad nauseam*. Years of trouble finding out the correct colours for World War I pilots' socks, and the actual amount of simulated dirt to put on to represent the conditions four days after D Day, at a location slightly south of Stalingrad. Building and finishing the true scale model is however only the beginning.

Once safely arrived at the flying field your pride and joy is picked to pieces mercilessly by innumerable "experts", who appear, magnetically, at the unveiling of any new model. Their apparently endless knowledge would have been invaluable during the design phase of the model, but somehow these characters are never around at this time. Slightly worse than the critical remarks of one's peers is the flying of the true scale model. Usually overweight and under-powered, the flying phase of the operation is fraught with anxiety. Will it take off, if it does will it fly, and then will it land? No wonder most scale modellers are grey haired. (Sorry Eric.)

The last item to discuss that sport modelling isn't is superior radio control, or money modelling. Here the object of the game is automation, and the major skill involved is the opening of the wallet. Only complete mechanisation of the model is good enough. Everything is controlled remotely. The fuel tank is filled by an electric pump. The motor is started by an electric starter. The model is then flown using an N-channel pre-programmable radio box which, if it only had a remote TV monitor attached, would save the owner the annoyance of even going out to the flying field, and having to mix with the proles.

I think that's about it for now, except a small comment that sport flying isn't indoor flying either, as there are better indoor sports than winding up two-pennyworth of elastic. It's time to get back to our main topic and now discuss what sport flying is.

It's pleasure, that's what it is, spelt **FUN**. This is something that seems to be lacking in most of the previously discussed endeavours. Now



rather than going on for the rest of this article saying it's fun, it's fun, it's fun, let's have a look at where this fun comes from.

What we'll actually do now is take a look at some of the sport models that I've concocted (they weren't seriously designed) which have given me lots of enjoyment over the past few years, and maybe some of this pleasure will be passed on to you.

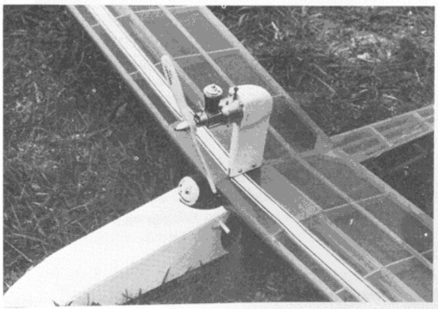
Note that all the models are radio controlled. I think that the introduction of simple radio control (you just simply stick it in the model), is one of the greatest benefits of all to the sport flyer. The time spent at the flying field is now mainly used for flying, rather than for chasing, or climbing trees which is certainly *not* what my models are intended for.

There are five plans shown here, all of models which are easily built, and easier to fly. If there's a preponderance of gliders it's because I like gliders, and also that my home is on top of the local hill. It's not my intention to discuss the constructional aspects of all these models in detail, rather I'd like to comment on each one, explain a little how it came to be, and things like that. Let's start off with the simplest one, the Tadpole X.

Tadpole X

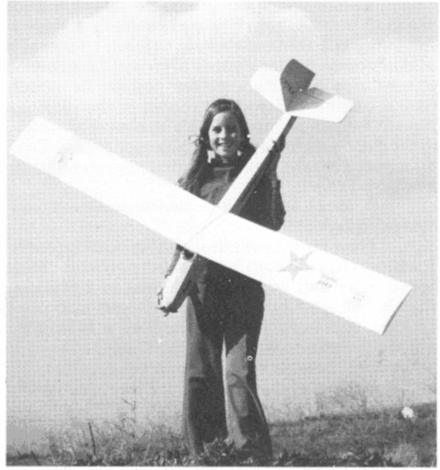
This is one of my favourite models, probably because it fits the formula that any model that can't be built in a fortnight isn't worth building (it's my formula). Several versions of the basic design shown in our sketch have been built, models with Vee tails, electric powered, with smaller wings, Jedelsky wings, and even a twice-sized version, which didn't look too good. The original is still in my attic, and flies occasionally when I can spare the radio for it. Like all single-channel models it suffers from the dreaded lack of penetration, which makes it limited for heavy slope soaring. However, this is a good feature, as it stops one flying the model when the wind is stronger than the structure.

Construction of this model begins in the model shop, with some time spent on wood selection. This type of "sparless" construction for the wing means that good wood must be selected for the leading and trailing edges, so take time selecting these pieces. Similarly the tail boom, which in addition to holding up the back end has to be rigid enough to be un-



Power Pod fitted to the Ezee-II makes it even easier for lone handed operation or where towline is awkward.

Liza Headley with her prototype Ezee-II, a first model, specially designed for easy balsa cutting and assembly.



responsive to the pulsed rudder frequency. One of my early models had the tail boom arranged wrongly, with the major axis vertical and would occasionally go into a wonderful resonance. Luckily it was self-damping. For an ultra-light model, cover the wings with tissue, but a Solarfilm finish is so much more durable, for a small weight penalty.

The model as drawn is mainly for slope soaring, and this, as I said before, because I happen to live on a hill that has several good slopes within easy driving distance. However, if you're a flat earth person, then a simple tow hook epoxied to the fuselage should turn the model into a thermal soarer. Likewise a powered version can be made by leaving off the nose block, and substituting a Cox Pee Wee. The possibilities are many. An even more durable configuration can be made by covering the wings top and bottom with $\frac{1}{16}$″ sheet, plus a simple full depth spar.

Ezee II

Ezee II was designed for my daughter to build. She hadn't built a model aeroplane before, but knew something about them, after tripping over models around the house in various stages of completion or decay for most of her life. A construction technique was evolved to take any hard work out of the model, and simplify some of the tasks the experienced builder takes for granted. Firstly everything was made from balsa, no plywood being included. Then all the wing ribs were straight lined, so that they could be cut easily with a knife. The actual aerofoil resulted from these triangular ribs and a few strategically spaced spars on the top of the wing. Another item was not to introduce any bends in the strips.

The resulting design looked rather angular, but was easy for small hands to build. Again this was basically a slope soarer, with two channels this time, as I think it's easier to learn to fly radio with two channels. For conversion to power a small plywood tongue wedged between the centre-section ribs permits a power pod to be attached if the winds fail. A typical engine and pod are shown in the photograph on p. 8. This makes a good beginners' model, it's reasonably slow, so that longish reaction times can be allowed in the learning process. Dressing up the model with a pilot and a bright finish will disguise some of the angularity of the basic model.

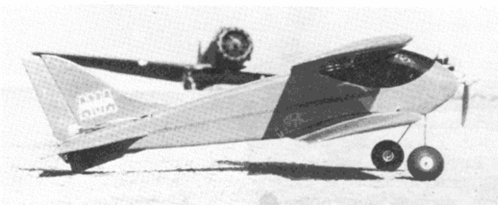
Sportbipe

Now for a power model. I've built biplanes off and on for numerous years, and have always been attracted to this configuration. This is possibly because my first aeroplane ride was in a biplane, a de H. Dominie, from R.A.F. station Church Fenton. It was also my last biplane ride. As you can see, this isn't a scale model of a Dominie, but a much more racy design. It's quite a small model, 24 in. span, and needs a small radio, because of the restricted space in the fuselage. The original was fitted with a Cannon two-channel set, but I have heard of successful flights using a rudder-only radio.

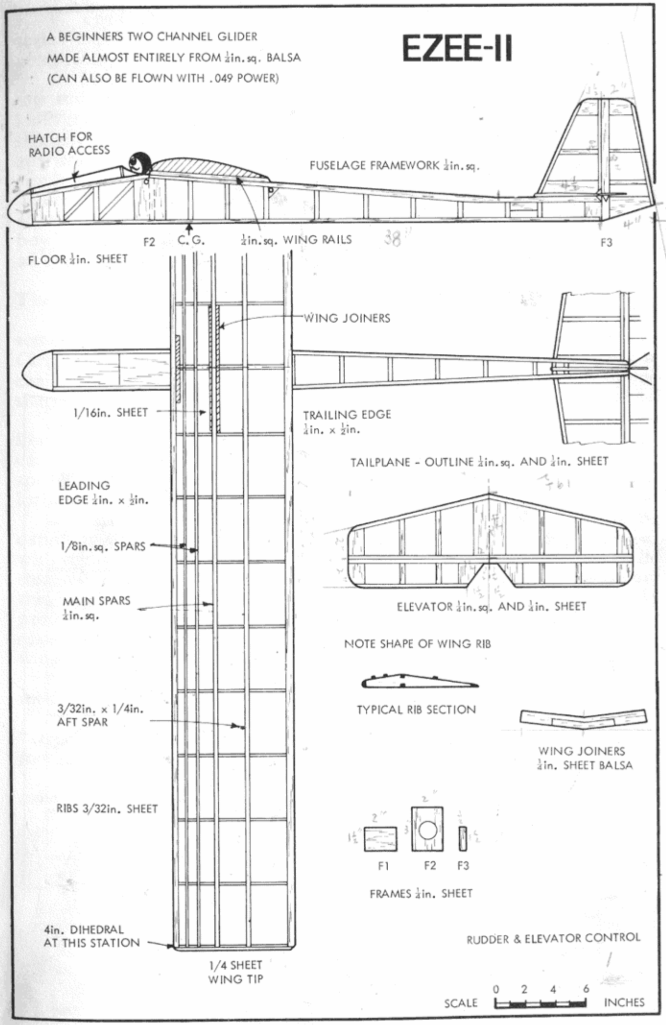
One of the problems I have with biplane designs is getting the proportions satisfactory. I usually end up with the wings too big, so my latest technique is now always to build the wing this way, but not to install the wing tips. The wing span is then decided after the uncovered model is assembled. The wings get cropped bay by bay until a satisfactorily balanced shape appears. At this stage the wing tips are attached. I found this to be a much easier way of getting the proportions right than spending time on endless amounts of sketches. Again the power plant is the ubiquitous Cox ·049. The only problem I've had with this engine is its annoying habit of sucking up debris into its air inlet, so that the engine has to be removed from the model for a clean-up job too often.

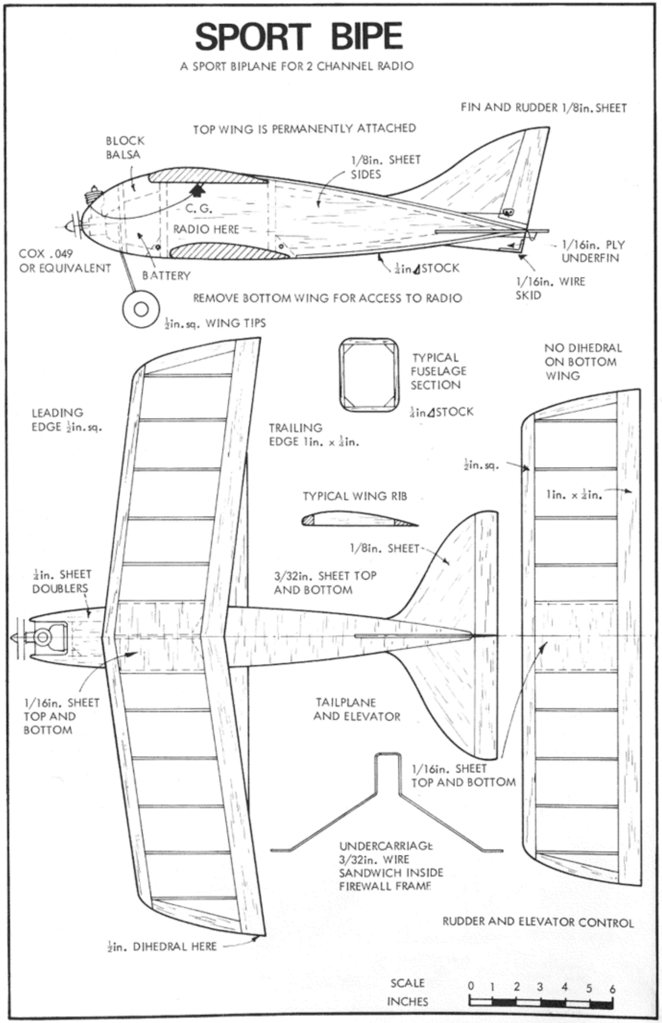
The Viper

Another power model, this time for three channels, for people with three thumbs. This is a somewhat bigger model, and was designed for rudder, elevator, and engine control. It's a scale model of a non-existent fighter, typical of something the French would have designed in the 1930's.



Sportbipe—a tiny model only 24 in. wingspan, for the light-weight R/C sets.





The beauty of making a scale model of a non-aeroplane is that the scale "experts" mentioned previously are baffled. Any sort of finish is acceptable, and cannot be challenged!

Model design is relatively simple, the fuselage is a box with formers top and bottom to produce the octagonal shape. The wing plan-form looks complicated, but it really isn't. Apart from the root rib the wing has a straight taper. Adequate dihedral is provided in the wings for a scale appearance, and the fixed wheels and spats also contribute here. Engine size is ·09 to ·15. The prototype had an OS Max ·10, which was adequate. There's no reason however, not to have a large engine for a sport model, after all some sports are more exciting than others, *e.g.* hang gliding and bowls. So why shouldn't some models be more exciting than others. After all sport models should not be restricted to replicas of Piper Cubs.

The Pfalz Alarm

Back to the gliders for the last design. This model was built to have something different on my local slope. At the time the sky was full of Cirruses (*or Cirri*) and the like, all aspect ratio and slinkiness, so the challenge was to make something equally good at flying and equally opposite in appearance, Pfalz Alarm was the answer.

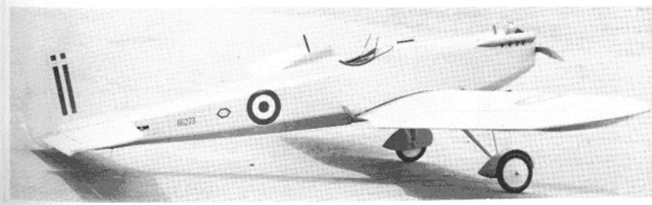
The main design for a slope soarer in my neck of the woods is a low wing loading. The local wind is a mild sea breeze, that appears in the early afternoon and disappears around sunset. Conditions are best in the spring, which is when I do most of my gliding. From experience, wing loadings in the 8 oz./sq. ft. seem to be ideal.

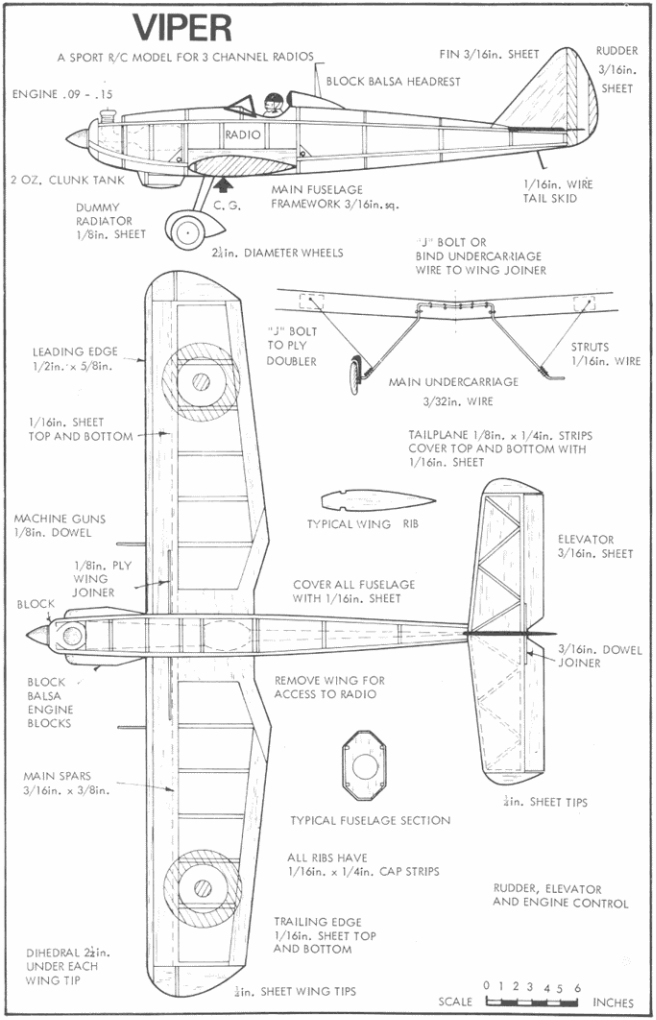
The P.A. was designed for this sort of weight, and proved to be definitely a good flier, and definitely an ugly model. One problem I had with the original was a built-in warp in the right wing, which had to be steamed out for every flying session. A sheeted leading edge should cure this, and the added weight should be no problem in windier climes. My prototype was finished in transparent red! (what else?). I did consider once a powered version of the P.A., with twin pusher ·049's behind the wing, but other projects got in the way, and it was never completed.

So much for the plans. What else is there that makes a good sport model. How about a simple scale model, with the emphasis on simple.

One of the recent trends in home-built aeroplanes (full size), is the "large model" concept. These are designs which look like scaled up models, and are usually very elementary structures. A couple of examples

Jack must have been inspired by the Dewoitine 500/510 when he created this attractive low-wing variation for three channels.



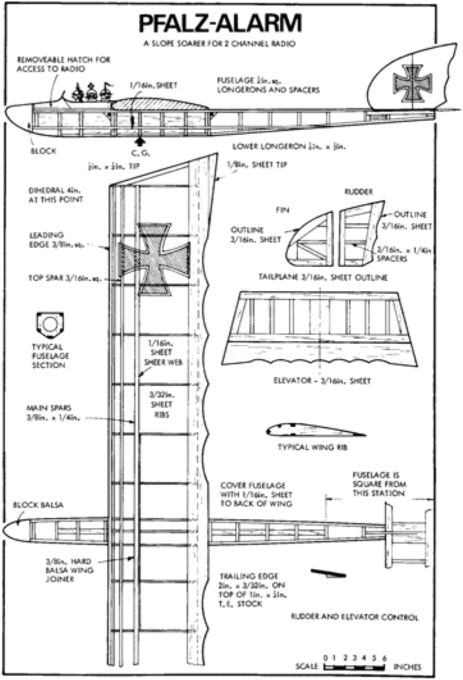


come to mind, the "*Volksplane*", and the *Livesey D.L.5*. I made a model of this latter design, which is shown in one of the illustrations. One advantage of building this model was, at the time, the full-sized version still hadn't flown. This solved the perennial problem of an authentic finish on my model! We're not always so lucky.

So much for the designs of the past. What of the future? Luckily with sport models the past can be the future. Old designs are just as pleasurable to fly (thanks to the miracle of R/C) as you think they were back then. There is no latest sport model, and no worrisome evolution. Of course improvements are always being made. We have better materials, glues, motors, and even more magazines. So the future looks good, and I don't see why it shouldn't continue to be so.

My final word. The main point I've tried to make in this rather rambling discourse is that sport flying equals fun flying. It really can't be written about, or down, it just is. *So go and do it!*

Pfalz Alarm in transparent red film covering to reveal its simple, stark construction, makes a change on the slope soaring site. Below is Jack's version of the Livesey DL5 home built suggestion made long before any full size has flown!



GREAT SPECKLED BIRD

by George Perryman

(From "Model Builder" and M.A.N.)

CURVED TIPS, polyhedral, long functional styling and a Vee tail signature are the hallmarks of Perryman, the legendary exponent of open rubber model designs. A key to the characteristic designs comes in the use of multiple spars, curved under tension, and the many laminated edges. All of which adds up to warp-free construction and excellent performance record. George told these stories of the background to just two of his best known "biggies" in *Model Airplane News* and *Model Builder*, and like our friends in N.F.F.S. who chose to make each a "model of the year"—we'd like our readers to share the Perryman magic—over to George. . . .

UNLIMITED RUBBER MODEL OF THE YEAR 1978

The *Great Speckled Bird*, with its gull wing, isn't exactly a new idea, since seagulls have flown pretty well with this configuration for several hundred million years. In the contest region where I fly, Unlimited (now Mulvihill) rubber was flown with Category II rules, with as many 3-min. flights as one could make, determining the winner. This method was followed at the Nats. until recent years, when after making 3 each 3-min. flights, progressive 1-min. increments were added: 4 min., 5 min., etc. With this increased flight time, design philosophy had to change. Now, instead of making a durable and reasonably good model, it put a premium on lighter, large (300 sq. in.) wing ships. Large, light ships fly better and remain in sight longer, so this seems the way to go.

Some designers follow the old saying of a little bit is good, so naturally a whole heap is better, when deciding how much rubber to use. I have tried both extremes, between too much rubber, and not quite enough. About 20 years ago I had a big 300 sq. in. job named the *Kluge*, which turned out to be aptly named. The fuselage was a full 7 feet long, and carried 24 strands of $\frac{1}{4}''$ rubber, 64 inches long, which weighed over 8 oz. The one advantage I found with this great chunk of rubber was that I never broke a motor. My winding arm gave out long before the rubber expired. If I could have got A.M.A. to let me use King Kong as proxy winder for me, I might have won the Mulvihill Trophy long ago.

On the other extreme, I built a lightweight 300 sq. in. ship, *Practically Nothing*, with sliced, hollow $\frac{1}{32}$ ribs, condenser paper covering, and an all-up weight of $2\frac{1}{2}$ oz., including rubber. The prop would run about 7 min. and this looked like the way to go for calm air contests. There always seems to be a hooker in all our best laid plans. How do you D.T. one of those things down? Until a few years ago, A.M.A. rules only permitted one model, and when you lost your gum band ship, the contest was over for you, so this effort was not successful either.

Frank Zaic included both these models in his Yearbooks, since he was probably hard up for material at the time.

I have tried many design approaches during the past 40 years, and am still searching for the "optimum" ship. Due to variability of weather and available rubber, there may not be such a thing as "optimum". The long, skinny, light model is probably best in light wind flying conditions, but in windy weather flying, with perhaps rain (and dust devils), a more durable ship is required. A case in point is my old 1940 Lanzo stick which I've flown for the past two contest seasons, as old-timer rubber and in Unlimited events. Some models are just "luckier" than others, this I believe. The Lanzo won 14 straight contests, 8 in O.T. and 6 in Unlimited. This was against some pretty tough competition, including Jim Jewis, and any of you who have flown against Jim, know what I've been up against. Jim is an amazing flyer, and when you beat him, you've usually won the contest. I feel as though he's one of my sons, but we would rather beat each other than anyone else. A shorter fuselage model, with firmer wood all over, is certainly easier to keep intact in rough weather, and bad retrieval terrain. Anyway, I'd rather have a clunker in a thermal than the "optimum" ship in a downer.

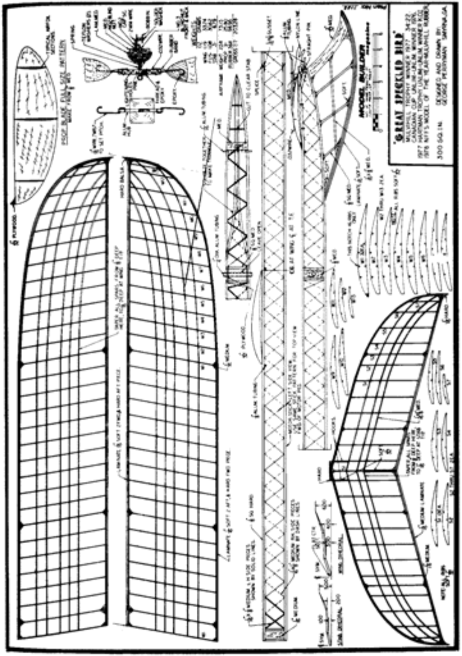
After all this rambling, I will say a few words about *Great Speckled Bird*. In 1976 I built two of them; one for average contest days we have around here, with maybe some wind and rain, and one a bit lighter for fly-off flights, since it would fly longer in so-called "dead air". I took both models to the 1976 Springfield Nats. to try once again to win the Mulvihill Trophy, which had eluded me for 35 years. Jim Lewis and I were going to fly alternately, so we might help each other chase if things got bad.

You remember me saying how some models are luckier than others? On my first official, using the calm-air ship, it promptly maxed, but went into the great beyond. A giant cornfield swallowed it up, and it was never to be heard from again (bet the corn picker had some interesting shades of tissue hanging from the inside gears). Jim's model landed near mine in corn too, but we found it this flight. We were flying Cat. II rules and my No. 2 "G.S.B." made its 3 each 3-min. flights easily, despite wind increasing. It made the 4- and 5-min. flights, and while flying for the 6-min. max., a "sinking feeling" hit me. A "sinking feeling" hit "G.S.B." also, since I launched into a giant downer. Neither Jim Lewis nor I could believe it was sinking so fast. We thought at first it had dethermalised, and 2·39 later, it was sitting on the ground like an old mother hen on her nest.

I had told Jim years before that a 6-min. ship would not make 2½ minutes in a downer and now he was a believer. In fact, the air was coming down so fast, it pushed a Dempster Dumpster straight down 3 ft. deep into the dirt. You may not choose to believe the last sentence, as I may exaggerate occasionally.

Jim went on in his usual fine style to win his second Mulvihill victory and set a new National Record to boot. He had to resort to using his old *Little Daddy* design of mine which he flew to the 1974 Mulvihill win, since his new long job fell again in the cornfield to join my No. 1 "G.S.B.", and was lost forever. At least two Southern models stayed together and wouldn't get so lonesome with all those Yankee models ensconced in the same cornfield.

Mike Bailey, another flying buddy from Smyrna, Georgia, and 1969 Mulvihill winner, flew his gull wing *Gully Washer* to second place just behind Jim. I was disappointed that the Mulvihill had slipped away



from me again, but was tickled pink that the Georgia boys did great.

The day after the Mulvihill episode, the Canadian boys from Toronto sponsored the unlimited rubber event for the Canadian Cup. This event was run the way contests were run back in the '20's and '30's, with a single flight, and the timer chasing the model by auto, motor-cycle, camel, covered wagon, etc. The timers back then were hardy souls.

Those of us who still had a model that wasn't in the corn, gave it a try. We all flew just after dawn, within a 5-min. period, into a breezy drizzle. Kathy (Monts) Learoyd was my timer, and with Rod Schneider, my 18-year-old flying buddy, helping me, we set off cross-country by auto, just after launch. *Great Speckled Bird* won with 6·02, with Jim Lewis only 12 sec. behind, flying his *Little Daddy*. Jim would have won easily, but had bad luck of landing in the top of an 80 ft. tree, and the only one in a 100-acre field. Mike Bailey with his *Gully Washer* made 4th, not far behind.

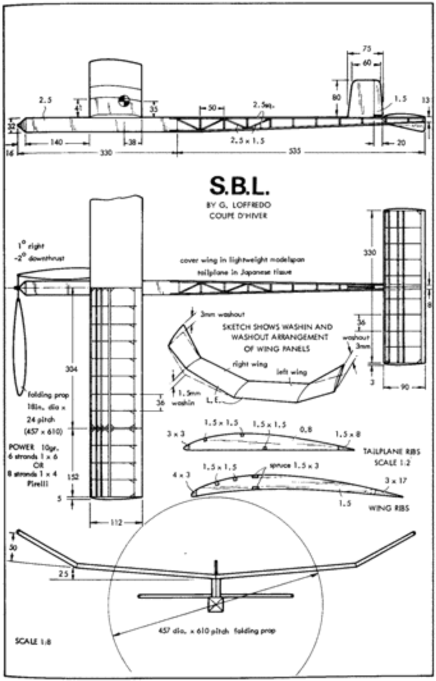
At the 1977 Riverside Nats. the weather was great, and I set about to once again try to win the Mulvihill Trophy. I had only been trying for 36 years, so fully expected to be bridesmaid again, since this had been my fortune many times before. Lady Luck smile on me, finally, and with help from my friends, won this elusive prize with a 34:22. Bud Romak was barely a minute shorter, with Jim Quinn, Bob White, and Andy Faykun close behind. I was very thrilled until that night at the old Timers' banquet, when John Pond and Carl Hatrak "framed-up" on me and announced that they had planned to present the Mulvihill Trophy to me, but A.M.A. had decided to retire it. After my having a couple of "fits", they went ahead and gave it to me (I'm giving them both a gift certificate for a 20-year stay on Devil's Island). At the 1977 King Orange Internats., "G.S.B." barely beat Jim Lewis and Phil Hartman, among others, in unlimited on a foggy, misty morning. "G.S.B." landed in a tree at 5·31, with Jim only 7 sec. down and Phil 7 sec. below Jim. After watching a couple of models, that flew just ahead of me, climb nearly out of sight in the fog, I decided to wind only about 75% max. turns and this proved to be barely enough.

I felt honoured indeed that the N.F.F.S. selected "G.S.B." as Model of the Year for 1978 in the Mulvihill rubber category, even though the design hasn't been around but a couple of years.

Mulvihill rubber models require a bit more care in handling and flying than any other outdoor type, due to their relatively fragile nature and size. With caution and luck they will outfly most any F/F type, however.

Since "G.S.B." is intended to be a competition model, and not designed for a beginner, I won't go into how to glue stick A to B; most experienced fliers can build as well as me, anyway. I will give the method I have used for 32 years to make prop blades. I've tried many different kinds of props over the years; some have done O.K., some not so good.

Use the plan to mark for cutting full-size blades from ⅛" sheet balsa. Sand airfoil shape just like a H.L.G. wing. Hold under hot water tap for a couple of minutes. Hold blade over electric stove ring, set on medium heat, and twist prop about 15° from root to tip until it feels dry. Let blade finish drying overnight at normal room temperature. Sand a bit, and give it a couple of coats of thin dope, then cover with Japanese tissue.



MODELLISTICA ITALY

Dope tissue 4 or 5 thin coats. This method is easy, and you can get both blades exactly alike in airfoil, shape and twist. I haven't carved a prop in so long that I doubt if I could, since using this easy method.

One word on construction of "G.S.B.", is to choose your wood carefully, since with "all them sticks" it is easy to end up with a model heavier than need be. The glide won't suffer much, but climb will be reduced. Weights shown on plans were made after two contest seasons of flying, and "G.S.B." was a bit lighter when first built (models and modellers both seem to pick up a little weight with time). If your "G.S.B." should end up heavier, it should still do O.K., maybe better, by adding a couple more strands of rubber than shown on plans.

Building is important, but flying is what makes or breaks a model. Balance at wing T.E., complete with motor, before gluing in wing dowels. Hand glide over grass and if model stalls, cut a bit off top of fuselage under the stab. T.E. If it has a nose-down attitude, shim under stab. T.E. Adjust rudder for gentle right turn in glide. Wind exactly 35 winder turns for the first flight. I'm superstitious and 35 is a lucky number, "G.S.B." should nose up slightly and into a right turn on this many. If it tries to stall in the climb, add a bit of downthrust. I build in about 1° down and 3° right thrust in the nose block, and this is usually pretty close. Increase winder turns when climb and glide looks O.K. I increase winder turns to 65, and if all looks well, 100, 150, and 200. I have never flown "G.S.B." on more than 900 prop turns, which is 85% of max. Have never flown full power in so-called "dead air", so don't know exactly what it will do, maybe 8 or 9 minutes. I remember many times laying on the crank and laying little pieces of rubber and tissue-covered sticks all over the landscape. Since I don't use a winding tube, I can't get "rank with crank" as "G.S.B." with a blown motor would be about like the Hindenburg at Lakehurst.

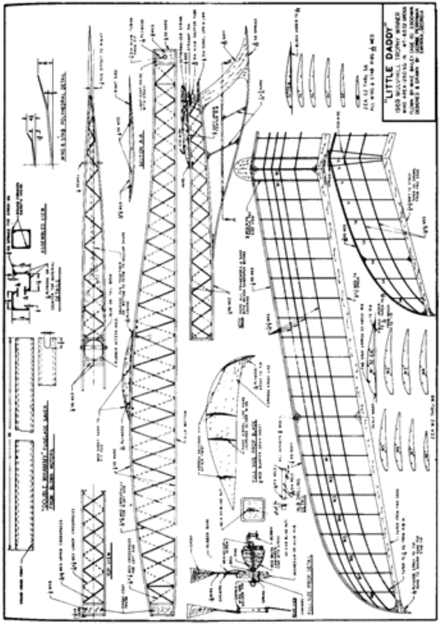
Have had good luck with F.A.I. Supplies rubber, as it is durable, relatively inexpensive and, best of all, available.

Rubber power is rapidly gaining in popularity, so why not give one a try? You can get more hours flying per dollar than most any type. Would be glad to hear from you if good fortune is yours with the *Great Speckled Bird*.

There is a sequel to the story. "G.S.B." is no more—a victim of its own fuse. When she dethermalised through trees in a fly-off at the 1978 Mulvihill, she landed in a ditch and suffered the ignomy of setting herself alight. By the time George located the remains, only the nose section and the prop could be salvaged. Moreover—George lost his title but with full honours to Joe Kubina's "Stratomax" (Heeb design). Joe (Detroit Balsa Bugs Club) celebrated his eighteenth birthday on the next day.

UNLIMITED RUBBER MODEL OF THE YEAR 1975
George Perryman's LITTLE DADDY

This is a typical Perryman model; distinctive appearance combined with good flyability. A two-time Mulvihill winner is a rare bird indeed. Jim Lewis built this model as his very first rubber model and proceeded to win everything he entered, including the 1974 Nationals. Mike Bailey won the Mulvihill with his *Little Daddy* in 1969. With this award we salute a man who has put forth perhaps more effort towards a single goal than anyone flying rubber models today, who is a fine "Southern Gentleman", and a true credit to free flight. George says about *Little Daddy*:



I'm indeed honoured to have *Little Daddy* selected as Unlimited Rubber Model of the Year.

Since the 1941 Chicago Nationals, I've had fond hopes of being a proud winner of the Mulvihill Trophy. Fate, so far, hasn't caused me a friendly smile to win this most historic relic. Since my Mamma didn't raise any kids who aren't hard headed, I'll keep giving it a swing.

It is a bit ironic that Mike Bailey, only 15 years old, flew *Little Daddy* to a Mulvihill win in 1969. This was his first attempt for this prestigious honour, and he made an even 33 minutes on a rainy day which was perfect for rubber. Another newcomer to competition in rubber models, Jim Lewis, the Georgia "Flash", showed us all how when he and *Little Daddy* again won the Mulvihill at Lake Charles in 1974. *Little Daddy* was the first contest type rubber model that Jim ever built. He has been a fine builder and flier of free flight for many years, but we were astounded when he won the first time out. He has won several other meets using *Little Daddy* and it's a great thrill to me to beat him occasionally. He barely edged the old master, Bob Dunham, for his Mulvihill win. *Little Daddy* was designed in late 1969, and started off winning. My number 1 son, Steve, set a Senior National Record, and I won Open in its first contest.

It was flown along with another spare model, *Big Mama*, in the world postal meet where it made 24 straight 3-minute maxes in one day, for a total of one hour and 12 minutes. I won't ever try such exertion again since it nearly put me in bed.

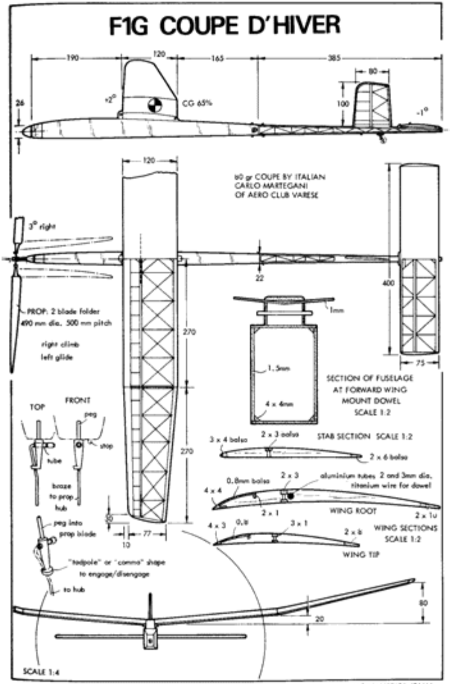
Some models are just luckier than others. My original *Little Daddy* is now 8 years old and I still fly the wing and stab. from it. So, it's both lucky and rugged. Unlimited rubber ships have inherently the weakest structure of any free flight type and special handling is necessary. To design a light, yet strong structure is a real challenge. Since it has many curves, I've been commented to many times about having crooked wood or a lopsided bench to build *Little Daddy*. The fuselage is shaped so that it adds a bit of lift while getting the wing up for pylon effect. There is also an advantage in the large profile since it stays in sight longer than a skinny fuselage on windy days.

The wing has 10° sweepback and the polyhedral stab. has 15° sweepback. After trying wings with 5° and 15°, 10 seems about the best. The pointed wing tips, stab. and prop tips are attempts to reduce vortex at the tips. I wont make any great claims for their effectiveness but it probably does no harm.

Propellers are a problem for many. Lacking a machine shop, I use a commercially available ready-made aluminium hub. The blades are sanded to shape from ⅛" medium weight balsa sheet and twisted to get proper pitch. I soak the blade in warm water for a couple of minutes and twist it by hand over a stove ring. The resulting prop seems to work out O.K.

Little Daddy is a forgiving model, but it will loop if not launched with a little right bank. Being left handed, I occasionally have trouble doing this properly. In closing, may I add a bit of caution while winding 16 strands of ¼" Pirelli. *Don't get too rank while turning the crank.*

Full-sized plans for *Little Daddy* are available from N.F.F.S. Plans and Publications, courtesy of *Model Airplane News* and *Great Speckled Bird* from *Model Builder*.



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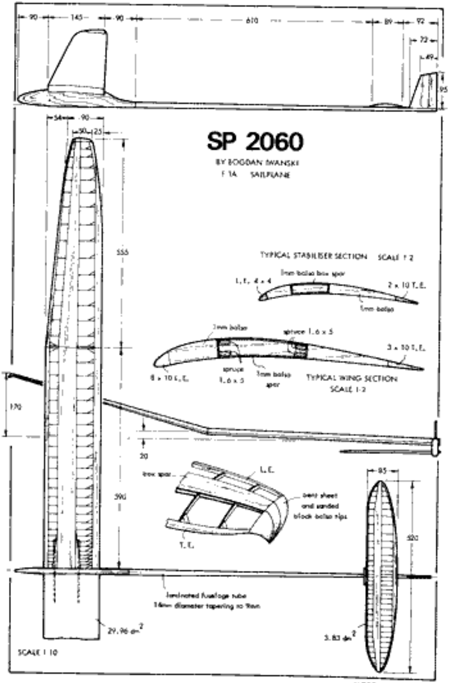
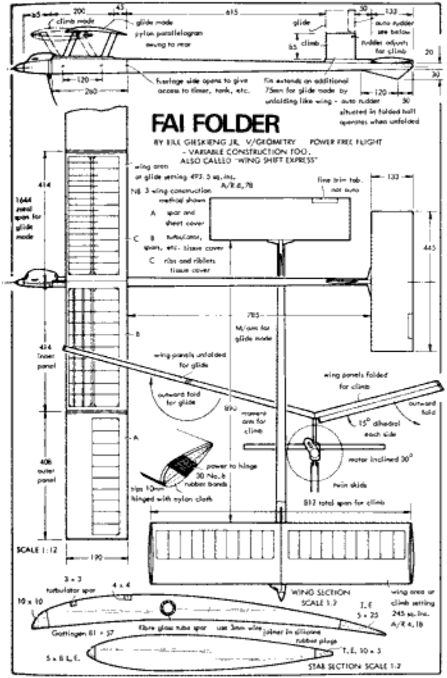
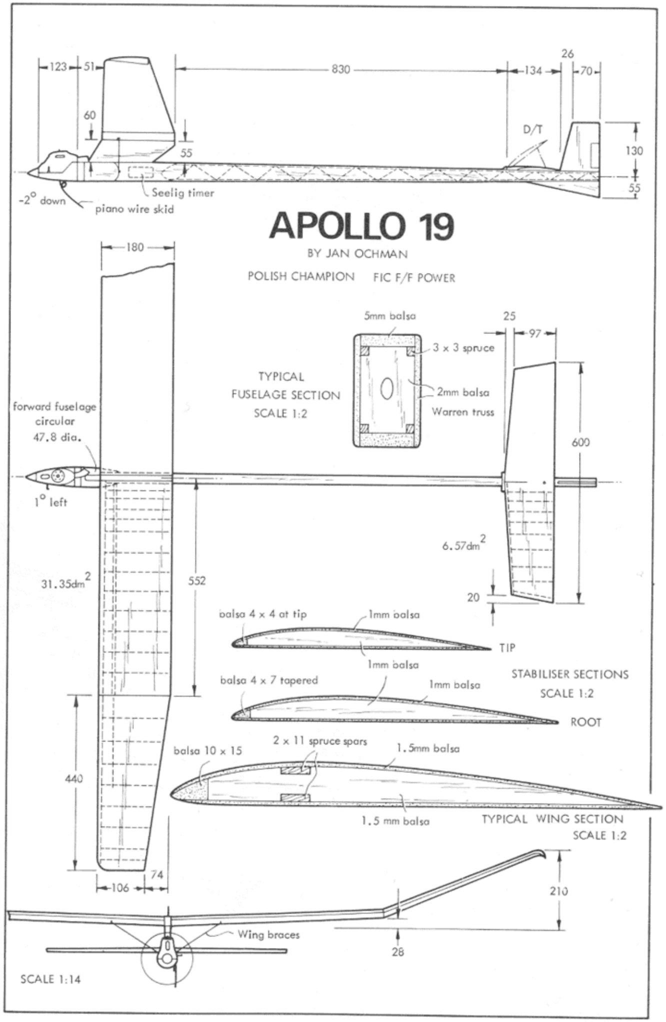


MODELARZ POLAND



MAGNIFICENT MOUNTAINMEN DENVER U.S.A.



MODELARZ POLAND


A power model wing and tail constructed by the author using eggbox principles. The wing has angled dihedral ribs to give increased incidence to the inner starboard panel, while all panels remain perfectly flat.

ASPECTS OF MODEL STRUCTURAL TECHNOLOGY

by Martyn Pressnell

AEROMODELLING TECHNOLOGY subdivides into essentially four separate areas of application:

aerodynamic design,
structural design and construction,
propulsion, and
flying.

Propulsion technology is usually bought by the aeromodeller in the form of engines, propellers and fuel, although in the more specialised fields of competition modelling, these items are frequently made or modified from commercial parts.

Each area of technology has its own technical problems, favoured solutions, rules of thumb for good practice, current styles or fashions, as favoured by their various practitioners and experts. The separate areas mentioned are not exclusive—there are many cross-influences, but they serve to provide a framework for the organisation of the subject.

Model structural technology and construction are closely-related areas of interest—the constructor of a kit model has bought the structural technology as represented by the plans and instructions and preformed components, but he will be faced with some, if not all, of the construction.

These two areas must be linked together, however, because it is impractical to consider structural design without taking account of the means of construction.

Thus this article is part technical and part practical.

Strength Requirements

Unlike full-size aircraft, model aircraft do not have any written airworthiness requirements or strength criteria which must be met. Nonetheless there are implicit requirements to which satisfactory models conform. As a novice modeller I built and flew several sport power models, the fuselages of which were of open balsa framework construction covered

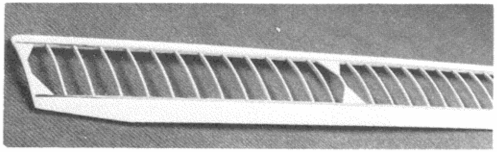


Photo 1: An A/2 tailplane with a very thin cambered aerofoil. Carbon fibre bonded to the LE and TE provide bending strength.

in doped tissue—may I mention *Hermes* and *Bandit*. They were prone to fracture just behind the wing or just ahead of the tail unit in heavy landings. The damage was too frequent to be tolerated and I soon learned to reinforce these areas, and the problem was eliminated.

In a high-performance competition model, this type of development has been taken to the "nth" degree. The selection of wood for its intended purpose, careful detail design of each component, reinforcement as necessary, crash-proof design, intentional fracture points, are some of the techniques in evidence. An excessively strong model, however, will inevitably be too heavy, with the result that impact loads are higher and flying performance suffers. Thus the criteria must be met, but not exceeded by more than a small margin. This requires fine judgement which is subjective—acceptable damage to one modeller is unacceptable to the next.

Choice of Material

Modellers are well versed in the use of balsa wood, spruce, plywood, aluminium alloy sheet, steel wire, and to a lesser extent the more modern materials such as G.R.P. cloth, G.R.P. tube, and carbon fibre with their associated adhesives.

It is found that these modern materials considerably add to the strength and durability of model structures but in the main do not secure any improvement in efficiency in terms of strength/weight ratio. Thus their use is restricted mainly to model types where weight is not crucial, or is

Table 1 MATERIAL SPECIFIC PROPERTIES

Material	*Properties*			*Specific Properties*			
	Density d lb./in.^{3}	Modulus E×10^{-6} lbf/in.^{2}	UTS ft×10^{-3} lbf/in.^{2}	Tensile Strength ft/d × 10^{-3} in.	Bending Strength ft/d^2×10^{-6} in.^{4}/lbf^2	Axial Stiffness E/d × 10^{-6} in.	Buckling Solid Sect. E/d^2×10^{-6} in.^{4}/lbf^2
Exp. Polystyrene	·0006	·00045	0·03	50	83	0·75	1250
Balsa soft	·0032	·30	0·92	288	90	94	29380
Balsa hard	·0069	·87	3·46	501	73	126	18260
Spruce grade A	·0144	1·50	10·0	694	48	104	7222
Carbon Fibre	·0646	32·0	330·0	5108	79	495	7663
Magnesium Aly	·0650	6·50	29·0	446	6·9	100	1538
Glass Fibre	·067	2·8	34·0	507	7·6	42	627
Aluminium Aly	·101	10·0	63·0	624	6·2	99	980
Titanium Aly	·163	17·5	156·8	980	6·0	109	681
High Tensile Steel	·285	29·0	125·0	439	0·17	102	363

fixed by the class rules F1A, F1B, F1C. Very limited use is practicable for open or unrestricted types. An example of the use of carbon fibre is shown in *photo 1*. This is an A/2 tailplane constructed with an exceptionally thin, cambered aerofoil section. There is insufficient thickness for conventional spars, but the leading and trailing edges, shaped from $\frac{1}{8}$" balsa sheet, are reinforced top and bottom by a bonded 50,000 filament tow of carbon fibre. This produces a tailplane of exceptional bending strength and stiffness. A similar application in a thin wing structure may well lead to a useful performance improvement.

Another modern material of interest is expanded polystyrene, which can have the lowest density of any material readily available to modellers, as low as 1 lb./cu. ft. It has little strength in its own right but it can be used to stabilise thin sheet balsa wood in the construction of wings or fuselages. It can easily be cut into long strips or conically tapering sections with a hot wire and on its own it may be used to form small wings, tails and fins. Its main advantage is in its simplification of construction by reducing the total number of parts, and it therefore suits some types of kitted models.

Table 1 compares the properties of various materials arranged in ascending order of density. For efficiency we are concerned with the specific properties of the materials, which control the strength/weight ratio of the structure. If we are concerned with specific tensile strength (as for a lower wing spar flange) carbon fibre is outstanding, but if we design down to the tensile load the requirement is for a mere hairlike strand, which would be useless for downbending of the wing. This is the dilemma with high-strength materials—their properties cannot be used to the full in modelling applications.

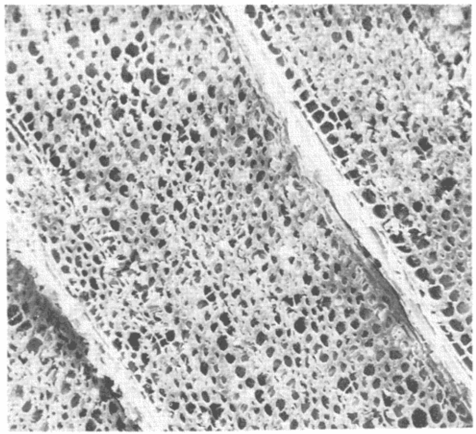


Photo 2: Electron microscope photograph of typical cross-section of balsa wood. Magnification 200 times full size. Note hexagonal cell structure, with rectangular cells in growth rings.

Where the choice of materials is based on the bending or buckling strength of solid sections the table shows that balsa wood becomes very attractive, and it is not surprising that it remains the principal modelling material.

Balsa Wood

Amongst the woods, balsa has the lowest density, due to its highly porous cellular construction. This is illustrated clearly by *photo 2* showing an electron microscope picture at a magnification of 200 times full size. The cells are mostly hexagonal and have very thin walls. The walls are slightly damaged by the razor cutting process although a brand new blade was used to prepare the specimens.

Photo 3 shows the cross-section of a piece of $\frac{3}{8}$″ dia. dowel at a magnification of 20 times. This reveals two other features typical of balsa wood which are discernible by eye by the careful observer. These are the pin-holes and the growth rings. Pin-holes result from the local collapse of the cell structure and occur throughout the sections examined at a pitch of about 1 mm. They are seen most clearly on the face of sheet or block, where they appear as brown lines $\frac{1}{4}$″ to 2 in. long. They are commonly regarded as the "grain" of the wood.

Balsa trees grow rapidly in hot and humid conditions, in the tropical rain forests of South America. This leads to growth rings which arise nightly (or daily?) and can be seen in *photo 3* at a pitch of 2 or 3 to the millimetre. On close examination in *photo 2*, these rings are seen to contain lines of rectangular cells in a "brickwork" pattern. These rings, then, are improperly expanded hexagonal cells, remaining in the rectangular state.

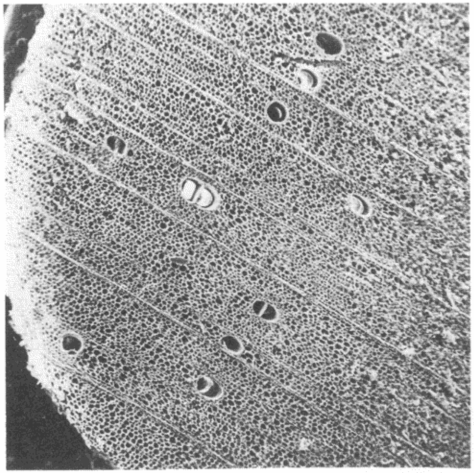


Photo 3: $\frac{3}{8}$ dia dowel at magnification 20 times full size, showing "pin holes" and growth rings

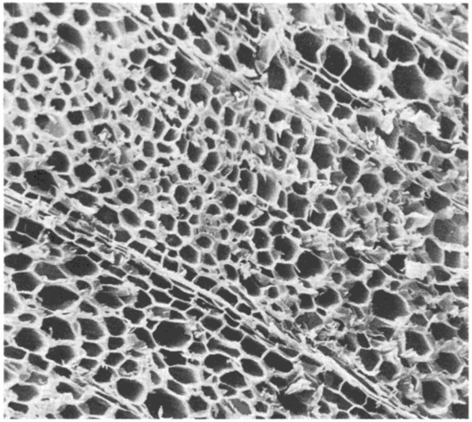


Photo 4a: High density balsa wood, 100 times full size.

Photos 4a and *4b* show sections of hard and soft balsa wood respectively at a magnification of 100 times full size. The variation of density is seen to be associated with a variation of cell size. Growth rings occur more frequently in the softer wood, suggesting it is associated with periods of slower growth rate.

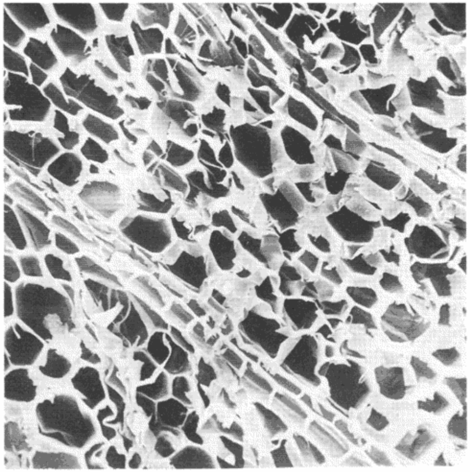


Photo 4b: Low density balsa wood, 100 times full size. Compare size of hexagonal cells, and pitch of growth rings.

Photographs 1, 2, 3, 4a and 4b are reproduced by kind permission of the Hatfield Polytechnic.

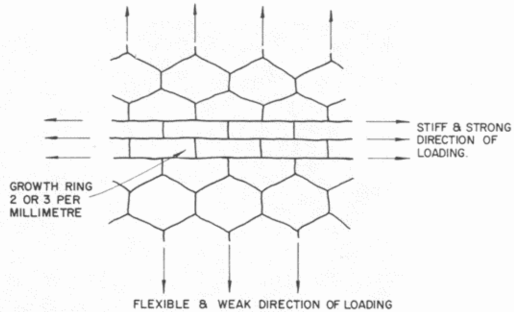


FIG. 1. BALSA CROSS GRAIN CELLULAR STRUCTURE

The direction in which sheet balsa is cut from the tree relative to the growth rings influences its strength and stiffness properties across the grain. Sheet cut tangentially to the growth rings is known as "quarter grain" or "quarter sawn" stock. It can be identified by small blotch-like areas of darker colouring on the surface, caused by the growth rings intersecting the surface at a fine angle. A better examination may be made by shaving the end of the sample with a sharp razor blade, when the direction of the growth rings may be seen with good eyesight.

Quarter grain wood is noticeably stiffer and stronger than other cuts when subjected to bending across the grain and is much sought after for cutting wing ribs. The reasons for these desirable properties are seen by reference to *Fig. 1*. Balsa sheet cut normally to the growth rings is flexible and suitable for rolling fuselages, but is weak across the grain, fracturing along a short growth ring. Except in these special applications, growth rings running diagonally through the sheet are preferable and this is the type most plentifully available; see *Fig. 2*.

Jigged Construction

The simplest form of jig is the flat surface—namely the building board—on which parts can be pinned during assembly. In addition to a

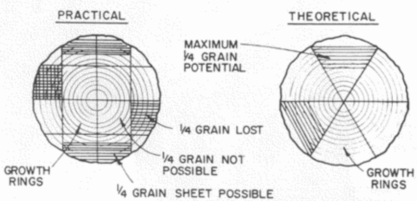


FIG. 2 BALSA TREE SAWING PATTERNS.

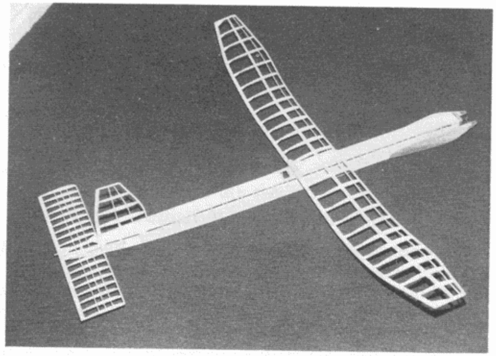


Photo 5: An open rubber model structure designed to withstand the rough and tumble of competition flying. Wing and fuselage utilise jigged construction.

few templates for wing ribs, wing tips, etc. it is all that is necessary to construct most wing, tail, and fuselage structures. An exception which has achieved a measure of popularity is to roll fuselages from sheet balsa wrapped around a suitable parallel-sided, or tapering, circular former.

However, the use of jigs extends the type of structure which can be built, and having overcome the psychological barrier of constructing the jig, new fields of innovation are revealed with possible trade-offs in terms of structural efficiency, model performance, and aesthetic appearance. *Photo 5* shows an open rubber model, the fuselage and wing of which depend on jigging principles. It is a model intended for the rough and tumble of competition flying in the worst weather conditions, and has served well in the intended function.

Construction of the fuselage is illustrated in *Fig. 3* and commences with the jig, step i, which is cut to the side profile shape of the fuselage from $\frac{3}{16}$" or $\frac{1}{4}$" sheet. The location of spacers and other features are drawn on both sides of the jig, and short pieces of $\frac{1}{16}$" × $\frac{3}{16}$" balsa are added to locate the longerons. The longerons, in this case $\frac{1}{16}$" × $\frac{3}{16}$" balsa, are attached to

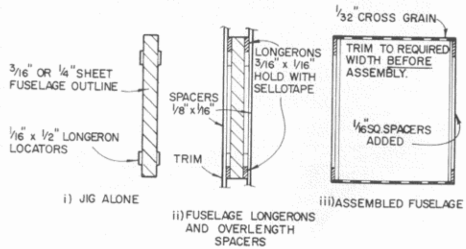


FIG. 3 JIGGED FUSELAGE CONSTRUCTION FOR RUBBER DURATION MODEL OR SIMILAR BUILT-UP TYPES.

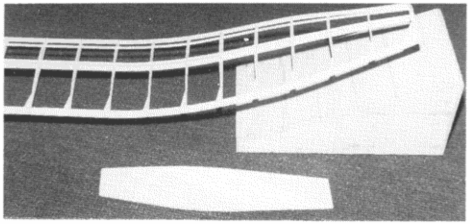


Photo 6: Curved dihedral construction, using simple ramp jig.

the jig with Sellotape, and spacers of $\frac{1}{8}'' \times \frac{1}{16}''$ are glued flat and overlength to the outside of the longerons, step ii. After trimming the spacers to length and sanding the edges of the longerons the side frame assemblies are removed from the jig and the spacers are reinforced by adding $\frac{1}{16}''$ sq. balsa between the longerons to form spacers of "T" section. Finally in step iii, the sides are joined top and bottom by cross-grain $\frac{1}{32}''$ sheet. A parallel section is incorporated in the fuselage profile so that longer models may be made on the same jig by sliding the side assemblies along at the appropriate point in construction.

The wing of this model has been built in one piece from tip to tip without any dihedral breaks, and curiously this method proves quicker than the conventional method. It is made possible by the adoption of an I-section main spar, the structural efficiency of which is now well known, and commonly utilised on competition and other types of models. The first step is to construct the wing flat on the building board with LE, TE, and all ribs, but omitting the spar. The LE and TE are then curved at the desired place by steaming. The lower spar flange $\frac{1}{8}'' \times \frac{1}{16}''$ is added, and easily bends to the wing curvature. The wing tip is then set on a ramp as shown in *photo 6*, while the top flange is added. On joining the flanges

Table 2 SUMMARY OF MODEL WEIGHT BREAKDOWNS (OUNCES)

OPEN RUBBER MODEL, Wing Area 260 in.^{2}

Component	Balsa etc.	Wire & Solder	Covering & Dope	Total
Fuselage	0·88		0·47	1·35
Wing	0·75		0·45	1·20
Tail & Fin	0·28		0·15	0·43
Prop & Noseblock	0·47	0·30	0·08	0·85
Airframe Total	2·38	0·30	1·15	3·83
Rubber	(maximum to suit fuselage provision)			4·00
Airborne Total	(subject to strength criteria only)			7·83

WAKEFIELD MODEL, Wing Area 244 in.^{2}

Component	Balsa etc.	Wire & Solder	Covering & Dope	Total
Fuselage	1·75		0·30	2·05
Wing	1·10		0·40	1·50
Tail & Fin	0·25		0·15	0·40
Prop & Noseblock	0·50	0·92	0·08	1·50
Airframe Total	3·60	0·02	0·93	5·45
Timing Mechanism				0·95
Ballast				0·35
Rubber	(subject to class rules)			1·40
Airborne Total	(subject to class rules)			8·15

with a $\frac{1}{64}''$ sheet web, grain vertical, the wing curvature becomes permanently locked into the structure.

Table 2 summarises the weight breakdown for this model, together with the weight breakdown of a Wakefield for comparison. The extent to which the more sophisticated construction of the open model leads to a much lighter structure is evident.

Membrane Loading

In addition to the airborne loads, and impact loads, for which a model structure must be designed, there are the membrane loads due to the taut fabric covering. The covering is fairly uniform in tension as a result of its dope shrinkage, but achieves this at the expense of putting the internal skeleton in compression. This is a permanent loading which can slowly cause the structure to creep. The problem of controlling this distortion is most acute with the lightest structures, and special techniques have been developed to cope with it. *Photo 7* shows a light rubber model illustrating an approach to the solution. With a wing area of 223 in.^{2}, the total bare airframe weighs 1·7 oz., covered it becomes 2·2 oz., and ready to fly with rubber 4·2 oz.

The fuselage is constructed with $\frac{1}{16}'' \times \frac{1}{8}''$ diagonal longerons with $\frac{3}{32}''$ sq. spacers assembled on a jig which is shown in *photo 8*. It may seem a mystery to some how the jig is removed from the structure. It is removed through the nose before the final two spacers on two opposite sides are inserted. Without these, the frame springs open on release from the jig and permits its easy removal.

The reason for using diagonal longerons is that they present the greatest strength in the plane of the resultant loading from the tight tissue. Fuselage design of this type is amenable to mathematical optimisation, and it is found the optimum design has equal weight of longerons and spacers. If we take the minimum practical spacer to be $\frac{1}{16}'' \times \frac{1}{8}''$ or $\frac{3}{32}''$ sq. balsa, and accept that a spacer pitch of 2 in. is about the maximum practical with $\frac{1}{16}'' \times \frac{3}{16}''$ diagonal longerons, it is possible to find alternative designs of equal strength and compare their weights. This is summarised

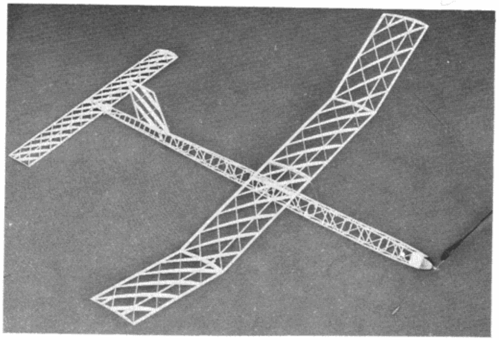


Photo 7: A lightweight rubber model, with structure designed to withstand membrane loading.

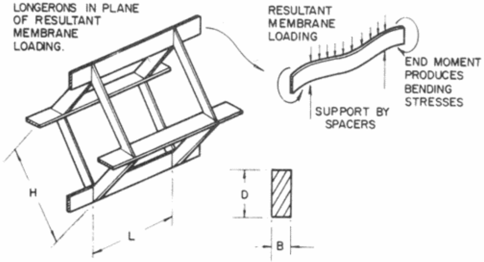
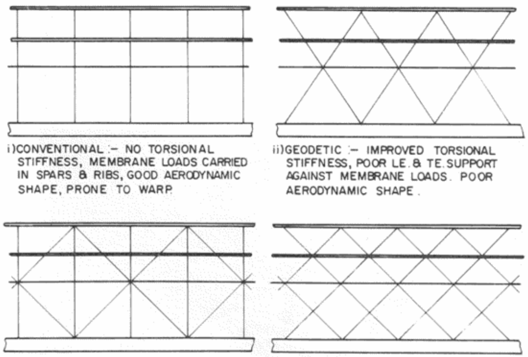


Table 3 COMPARISON OF FUSELAGE STRUCTURE CROSS-SECTIONS (WEIGHT) FOR CONSTANT LONGERON BENDING STRESS. H=1·625 in. ASSUMING SPACER DENSITY=80% LONGERON DENSITY

Longeron B × D in.	Spacer B × D in.	Pitch L in.	Fus. Structure Cross-section in.²	Per cent	Remarks
$\frac{1}{8}\times\frac{1}{8}$	$\frac{1}{16}\times\frac{1}{8}$	1·89	0·084	125	Popular
$\frac{3}{32}\times\frac{3}{32}$	$\frac{3}{32}\times\frac{3}{32}$	1·23	0·072	107·6	Popular
$\frac{1}{16}\times\frac{3}{16}$	$\frac{1}{16}\times\frac{1}{8}$	2·00	0·067	100	Datum-typical
$\frac{1}{16}\times0{\cdot}131$	$\frac{3}{32}\times\frac{3}{32}$	1·395	0·066	97·5	Opt. for spacer
$\frac{1}{16}\times\frac{1}{8}$	$\frac{1}{16}\times\frac{1}{8}$	1·34	0·062	92·3	Practical optimum
$\frac{1}{16}\times0{\cdot}123$	$\frac{1}{16}\times\frac{1}{8}$	1·31	0·0616	91·7	Opt. for spacer

in *Table 3*. The practical optimum structure is found to use $\frac{1}{16}'' \times \frac{1}{8}''$ longerons with 1·34 in. spacer pitch, showing an 8% weight saving on the bare framework.



i) CONVENTIONAL :– NO TORSIONAL STIFFNESS, MEMBRANE LOADS CARRIED IN SPARS & RIBS, GOOD AERODYNAMIC SHAPE, PRONE TO WARP.

ii) GEODETIC :– IMPROVED TORSIONAL STIFFNESS, POOR LE. & TE. SUPPORT AGAINST MEMBRANE LOADS. POOR AERODYNAMIC SHAPE.

iii) UNION JACK :– BETTER TORSIONAL STIFFNESS WITH RIBS CROSSING AT 90°, LE. & TE. SUPPORT RESTORED, GOOD AERODYNAMIC SHAPE.

iv) EGG BOX :– DOUBLE TORSIONAL STIFFNESS OF iii), IMPROVED LE. & TE. SUPPORT, MEMBRANE LOADS CARRIED IN RIBS. NOT PRONE TO WARP.

FIG. 4 COMPARISON OF WING CONSTRUCTION PRINCIPLES.

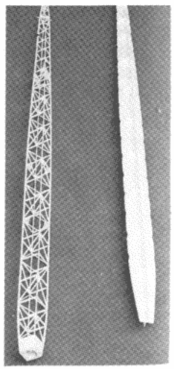


Photo 8: Jigged fuselage construction, using diamond diagonal longerons, and diagonal bracing for torsional stiffness.

Although "geodetic" and "Union Jack" wing construction are quite common in the U.K. we seldom see "egg-box" construction as seen in *photo 7*. These each considerably enhance wing torsional stiffness, but have other characteristics as shown in *Fig. 4*, to take into account.

Egg-box Construction

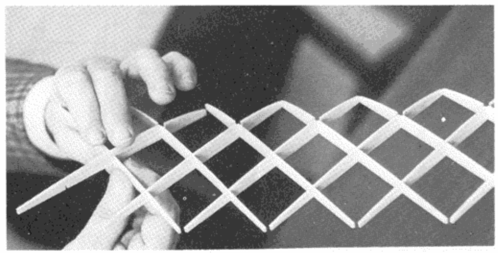
Egg-box construction at first sight gives the impression of being complex, difficult to construct and not apparently worth further consideration. In reality this is not so. Egg-box construction more closely resembles the structure of the World War II Wellington bomber, than does geodetic construction, the name adopted by Barnes Wallis for his design.

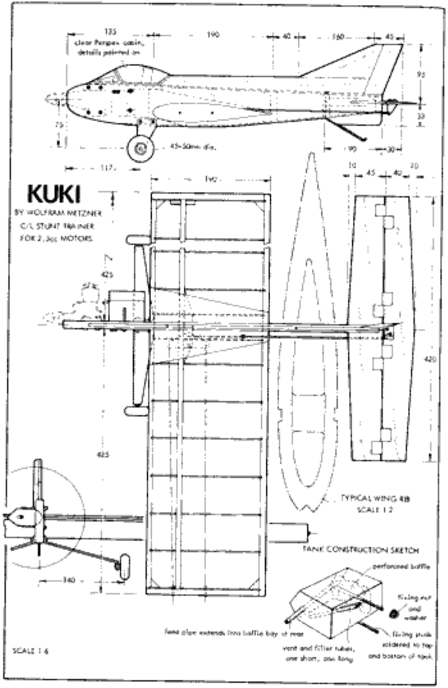
In comparison with "Union Jack" construction, egg-box is simpler because there is only one rib profile, and it requires no half ribs cut to fit. Equal torsional stiffness may be obtained with ribs of half the thickness while saving rib weight, and better support of the leading edge and trailing edge may lead to further weight savings there. Construction proceeds by cutting out all ribs complete, without spar slots. Half the ribs are blocked together and sawn through half their depth from below at the points of rib intersection. The remaining half of the ribs are blocked and sawn from above. These can then be assembled into a rib concertina as shown in *photo 9*. The concertina may then be pinned to the building board, for trimming to receive the leading and trailing edges and for slotting for the spars. P.V.A. adhesive should be used at the rib intersections, balsa cement causes closure of the sawn slots with resulting twisting of the structure on release from the building board.

Having built egg-box structures, further advantages emerge. The ribs provide a stiff shear connection between the spars if placed at the rib intersections, as well as to the LE and TE. As a result, all the spanwise members work effectively in resisting wing bending. It is possible to omit webs between the top and bottom flanges of "I" sections, and indeed an ultra-light structure consisting of LE, TE and a single top spar becomes practicable. On tailplanes and fins, not designed primarily by bending considerations, thin spars, *e.g.* $\frac{1}{16}''$ sq., may be located between rib intersections to maximise their local support.

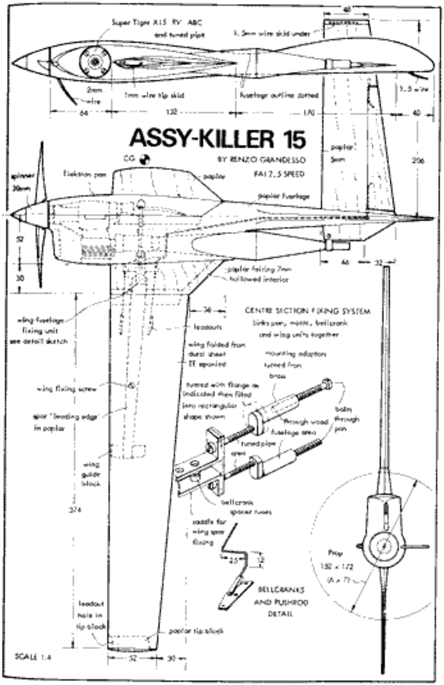
Membrane loads are resisted almost equally in the chordwise and spanwise directions by the egg-box ribs. Thus this construction does not tend to distort and has the stiffness to resist any such effect which may arise.

Photo 9: Eggbox construction. Commence by assembling slotted ribs into a "concertina". Trim to take LE and TE spars flat on building board.

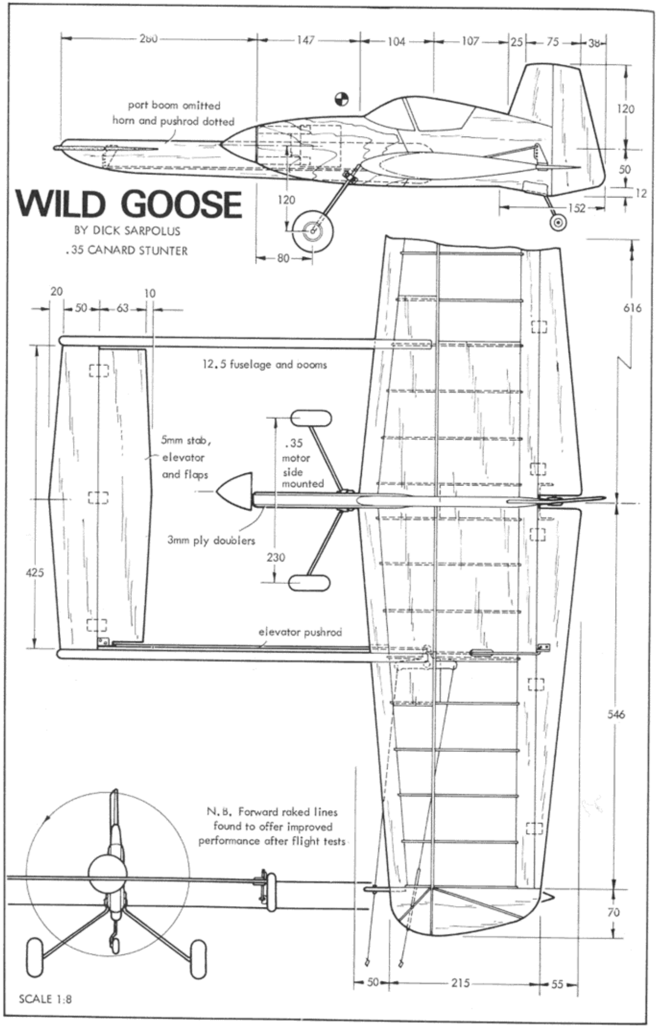




MODELLBAU HEUTE EAST GERMANY



MODELLISTICA ITALY



FLYING MODELS U.S.A.

Early stage in the 1978 T/R Semi-Final at Woodvale has U.K. team temporarily in the lead by one lap.

TEAM RACING
FLYING TACTICS, FLYING RULES AND RACE PERFORMANCE

by Marlon Gofast

(from "The C/L Speed & Racing Gazette")

WITH CLOSELY called flying fouls and a Sporting Code which is open to interpretation in a few areas as regards flying technique, flying style and the judges' interpretation of it, can have a major effect on the outcome of team race competition. Now the F.A.I. Sporting Code for Aeromodels is far superior to the A.M.A. rule book in this area so one doesn't want to advocate anything as silly as adopting the A.M.A. rules, but, as good as the F.A.I. rules are, there is still room for improvement.

The rules can be divided into two categories, written and unwritten. For example, the World Championships were run for about ten years using an unwritten rule that three flying fouls were required before disqualification. There was nothing in the rule book all that time to even hint at this procedure; all the sporting code did was enumerate the causes for disqualification implying that once was enough.

Just plain change won't make things better of course. To make things better one has first to have a concept of what *better* means. I think that "better" in this case can mean, for instance, a reduction in the ability of the pilot to improve race performance through towing the racer and blocking others. It also means making uniform flying standards easier to enforce. In addition, judges and pilots should be equally aware of the relation of flying technique on race performance. The minute one side is substantially smarter than the other, races can be decided by gamesmanship.

There's a determined Dane in each of these melees, small wonder he collected a silver 2nd medal when all was over—look for the strong uppermost wrist each time.

In writing this I have two purposes. The first one being to improve the rules, or at least the way they are interpreted. The second being to help competitors overcome the effects of blocking and make the most out of what they have. It may not make for easy reading all the way through, but how many things that are really worthwhile are easy? (On the other hand, how many things that were hard were worthwhile?)

SECTION 1

Before one can talk about flying in competition, the speed when flying alone, as it is affected by the way the flying is done, has to be pretty well understood. To this end I will try to show in the first section how pilot action is connected to the speed the racer is timed at. This section will end up with a method of estimating just how much speed is gained or lost by any flying technique.

Assume that there is a pilot in the centre, flying inside the three-metre-radius flying circle, and someone on the outside with a stopwatch timing him (and for ten laps please). The person on the outside compares the speed from the ten lap times. This is only an apparent speed as, for example, if the plane is flown arm extended the distance covered is more than one kilometre per ten laps; but the formula used for speed calculation assumes the standard one kilometre distance for ten laps that, say, an F.A.I. speed plane flies when in the pylon.

Since everyone has electronic calculators these days, the formulae are given below. Although rounded off, they provide more accuracy than

you need even if you are timing with a millisecond timing error.

speed in kilometres/hour $= 3600/T$
speed in miles/hour $= 2237/T$

T, in the formula above, is the time in seconds to fly ten laps. The reason for using this as the speed is that it is the only one we can measure and it is the only thing that really counts.

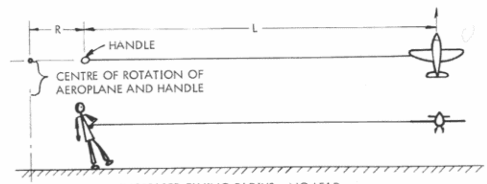
Now that this person is assumed to be out there flying, let us perform some experiments to determine the relation between speed and technique.

The easiest effects to understand are those that occur when the plane is flying a circular path—no "yo-yo" (*e.g.* pulling the arm in to suddenly reduce the flying circle radius) and no wind. If the pilot is leading or holding back on the aeroplane, he does so continually, not just for a fraction of a lap. The handle and the aeroplane will both move in a circle at a steady rate. In short, what is called "steady state operation" is established. Under these conditions there are two kinds of effect; those due to changed flying radius and those attributed to power added (subtracted) by leading (holding back) on the 'plane.

For discussion purposes, say that the speed achieved when flown from an F.A.I. pylon is the standard. Compared to flying from a speed pylon, if the 'plane is flown according to the new team racing rules (centre of rotation, handle, 'plane all in a line), the line length is effectively increased. Except for a tiny increase in line drag, the true airspeed will not change. The speed (based on time per lap) goes down because the aircraft flies further than one hundred metres per lap. If the pilot's hand moves in a 1-ft. (·3-metre) radius circle, for example, and the handle is

Table 1 Approximate Dimensions for Figures 1 and 2 Data Given in Imperial and Metric Units.

Figure	Line length l	Handle path radius r	Aircraft flying radius	Apparent gain in speed for a 100 mph racer	Change in ten lap time
1	52·22 (15·92)	1·0 (·30)	53·22 (16·22)	- 2·0 (- 3·2)	+·43
2	52·22 (15·92)	1·0 (·30)	51·22 (15·62)	+2·0 (+3·2)	-·43



INCREASED FLYING RADIUS - NO LEAD

FIGURE 1

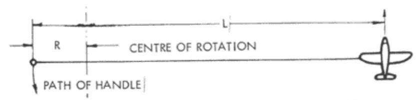


FIGURE 2 DECREASED FLYING RADIUS - NO LEAD

between the aeroplane and the centre of rotation, there is about a 2% decrease in timed speed (see *Fig. 1*). If the pilot gets way "behind the plane" the lines pass over the left shoulder (centre of rotation between the handle and plane' and the effect is reversed (see *Fig. 2*).

Note from *Fig. 2* that shortening the radius means the pilot must lean toward the plane while he flies and the lines will come off his left shoulder. Increasing the radius just reverses things. Note that the net change is ·86 seconds in the time to fly ten laps and neither pilot is "whipping".

The discussion above illustrated apparent speed change by changing flying radius without whipping. These two cases will be maintaining the same flying radius (approximately), but changing speed by leading or lagging, one might call it the "pure whipping case". The first one, shown in *Fig. 3*, is the natural posture most beginners and sport fliers assume without being instructed. The pilot walks around in a circle with the lines perpendicular to his shoulders. In *Fig. 4*, the pilot walks backward right after a pass in A.M.A. competition or, as some stunt fliers do, between manoeuvres to get high manoeuvre entry speeds. By calculation for an example world class racer, the speed lost is five mph in *Fig. 3* and in *Fig. 4* the speed gained is six mph. The reason the gain is more than the loss is the feedback; the pilot whips, the aeroplane speed increases, increasing the line tension which further increases the effect of whipping.

Table 2 summarises the four positions discussed so far and how to detect them. In each case a line drawn from the centre of rotation will go right through the shoulders of the pilot. This will not be the case in intermediate positions.

There are a lot of flying stances other than the four just discussed, of course, and they all involve leading or lagging the aeroplane. That is the handle will be ahead or behind a line drawn through the centre of

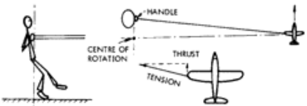


FIGURE 3 FLYING RADIUS - LINE LENGTH PILOT LEADS AEROPLANE

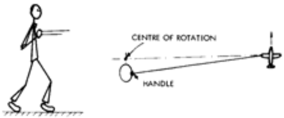


FIGURE 4 FLYING RADIUS - LINE LENGTH PILOT LAGS AEROPLANE

Table 2 FOUR BASIC FLYING POSITIONS AND IDENTIFYING FEATURES

Increased flying radius, no lead (*see Figure 1*)
- pilot leans away from plane
- shoulders parallel to lines, right shoulder closest to plane
- pilot and plane face the same way
- pilot seems to walk straight ahead

Decreased flying radius, no lead (*see Figure 2*)
- pilot leans toward plane
- shoulders parallel to lines, left shoulder closest to plane
- pilot faces the opposite direction of the plane
- pilot seems to walk straight ahead

Little change in flying radius, pilot lags plane (*see Figure 3*)
- pilot faces plane
- shoulders at right angles to lines, left shoulder toward centre of rotation
- pilot seems to walk straight ahead

Little change in flying radius, pilot leads plane (*see Figure 4*)
- pilot faces plane
- shoulders at right angles to lines, right shoulder toward centre of rotation
- pilot walks backward

rotation and the aeroplane. If the handle is ahead of the line (displaced in the direction of flight) then the pilot is leading the plane, commonly called "whipping", and if the handle is behind then the pilot is lagging, for which condition there is no slang word equivalent. For those of you who would like to coin a word, here is the place—it could be called whoaing or maybe dewhipping....

On an F.A.I. team racer the line tension is from 10 to 15 lb. (44 to 67 Newtons) for most planes. This force causes a power input to the plane. The faster and heavier the plane the more added power for a given lead: the more horsepower that's taken away for a given lag too.

To help fix ideas, a specific example will be given. Consider a world-class racer capable of flying at 100 mph (161 km/hr) in a pylon, and with a mass equivalent to a weight of 1.00 lbm (454 g). In an F.A.I. speed pylon the line tension would be about 12.8 lb. (56·9 Newtons). Assume the pilot flies with the handle 2·0 ft. (·61 metres) from the centre of rotation and leads the plane by ·5 ft. (·15 metres). The power input to the plane from the line is ·165 horsepower (4·53 watts). Considering that the thrust power from the engine is about ·4 horsepower (11 watts) (this includes propeller efficiency), this is a substantial increase. The top view in *Fig. 5* shows what is meant. Clearly the racer will lose some speed because it is flying in a larger radius circle, but it will also gain because the aeroplane will fly faster due to the extra power. The whole problem is then to find out exactly what the net effect is, considering both effects. As it turns out, in this example there is a net loss of about one mph.

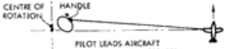


FIGURE 5 PILOT LEADS AIRCRAFT FLYING RADIUS INCREASED

I have done a lot of calculation, but to explain what was done without going through a bunch of formulae the assumptions and explanations are given as follows: The position is to calculate the resulting change in apparent speed for any given aeroplane. First, the effective flight circle radius from geometry is computed. The centrifugal force is then related to the line tension and the line tension plus the lead (lag) of the lines relative to the aeroplane show how much extra thrust is being applied. Assuming that the engine thrust power was constant, the resulting increase in air speed is computed. This, in effect, assumes that the power required is proportional to the cube of the flying speed. Once the flying speed is known and the effective flight circle radius is also known the time for ten laps and the apparent speed can be computed. I've done all this for many cases and the results are shown in *Fig. 6*. Calculations are done for the assumed world class racer described above. To use *Fig. 6* just imagine the centre of rotation is as marked, the plane way off the paper in the direction indicated. Then imagine the handle position somewhere in relation to these and read the gain or loss in speed off the graph. The positions shown in the figures are marked on this graph by a small dot and the corresponding figure number next to it.

From *Fig. 6* you can see that the "normal" flying position is somewhere between point 1 and point 4 and the flyer is losing a little speed compared to what he could do flying from a pylon. To make up for the speed lost by flying in a larger radius in a pylon the pilot must lead the plane. As can also be visualised in *Figs. 5* and *6*, "position 5" flying (which isn't whipping much) requires that peculiar crab-like walk pilots do while looking over their shoulders. Getting on the other side of the centre of rotation over toward position 2 really helps a lot. If you want an excellent

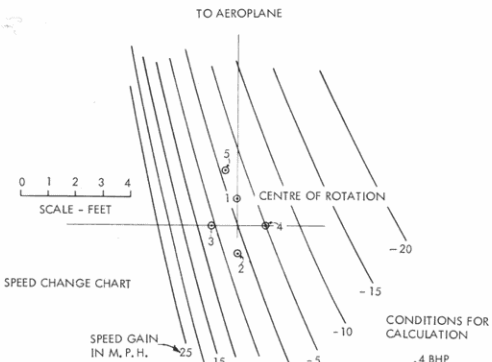
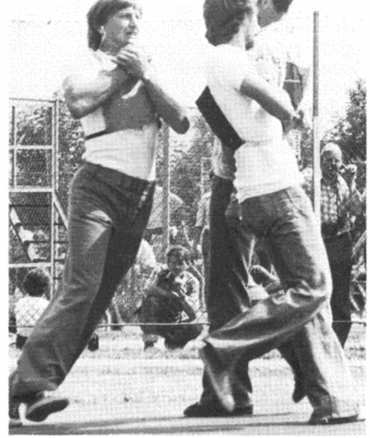


FIGURE 6



THAT PICTURE—as Marlon Gofast refers to it. From *Aeromodeller* October '76, shows how to get on the other side of the centre of rotation. Krasnorutski (left) is leaning forward and Petersen (right) is leaning backwards while Onufrienko at rear is reasonably upright.

example of something close to this picture see the picture of Petersen of Denmark on the way to a 3:56·7 time on page 584 of the October 1976 *Aeromodeller*. It's worth 1000 extra rpm. You might argue that the rule book outlaws position 2, but the jury has to call it.

In the first part of the article, flying alone in steady state conditions was discussed. The end of flying alone section will consider unsteady effects, namely: acceleration, wind change of flying radius, pull-ups and high flying.

Wind has an effect on speed as does acceleration and deceleration. For the world class racer used in previous examples (1 lb. weight, ·4 thrust horsepower, 100 mph when flown from a pylon), assuming that the racer accelerates to its terminal velocity while being flown from a pylon, it takes about ·7 sec. to go from 90 to 95 and ·7 sec. to go from 95 to 97·5 and so on. In other words, near terminal velocity takes ·7 sec. to get half-way to steady state speed from whatever speed you start and that goes whether you're slowing down or speeding up. Now, of course, this slow creep up to racing speed is not good and most pilots will give a little tug to pull the flying radius in right at the end to hurry the process up. When flying speed is disturbed in a race it always takes time to build it back up again, which is the reason to avoid sharp pull-ups which will drag the speed down.

Wind generally has (in small doses) little effect on average speed. When the 'plane flies dead into the wind the airspeed is higher than normal as inertia is still carrying it, but its ground speed is low. Around

18° after coming full into the wind the aeroplane is going the slowest in terms of ground speed and 180° around from that, the fastest (see *Fig. 7*). Wind does, however, offer a good opportunity to make whipping more effective. When the ground speed is the highest the line tension is the highest and the whipping most effective. The best place, therefore, is around either side of the 18° from downwind position. This is where a pass should be made. Going into the wind is the time to shorten the flying radius. Speed and line tension are low so whipping isn't as effective and no one can get away with leading the aeroplane around over the whole lap anyway. The foregoing suggests a pattern seen once in a while. The pilot (especially in a two-up situation) flies in "position 2" apparently way behind the plane and going like stink. Just before the plane has the wind square on its tail, the pilot starts his pass, raising his hand over his head and pivoting to his left on his right foot and taking a few backward steps while completing the pass. By this time the plane is going like a bomb—about 5 or 10 mph over speed—for whipping. Joe Turkey, whom he just passed flying in "position", is losing 5 mph so he's wondering where the hot dog's 10–15 mph speed advantage came from. About now, the faster plane is coming into the wind, the jury is scowling and thinking of calling a foul when the pilot stops the whip, turns around and starts flying lines off the left shoulder again. In two more laps he will be ready for another pass at this rate.

The foregoing discussion briefly touched on the effect of acceleration and wind. The penultimate effect to be considered is the "yo-yo". Since angular moment conserved, if the flying radius is shortened very rapidly, the speed has to go up. The time per lap goes down even faster than the speed increase would indicate as the flying radius is also shortened. Of course, the speed immediately begins to die down to the steady state

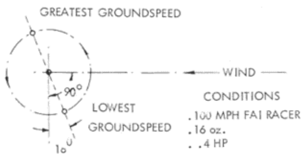


FIGURE 7 EFFECT OF WIND

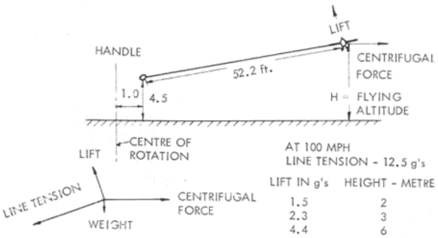


FIGURE 8 (DIMENSIONS IN FEET)

The Yo-Yo comes into play at Woodvale. Take-off from a fast pit stop is pulled to speed by that determined Dane.

speed, but for a second or so it helps, possibly just long enough to make a pass. The instantaneous apparent speed goes up as the square of the ratio of the old and new flying radii. After takeoff, for example, as the pilot spirals inward toward the centre, this effect really helps. If the example racer is doing 90 mph airspeed at a 55-ft. flying radius the apparent speed is 85·4. By suddenly pulling the radius in to 53 ft. it jumps up to about 92·0. The biggest increase in speed is when the aeroplane is going fast, so this spiralling into the centre should not be done right after take-off. Probably the best place is right at the end of the first lap, the pilot taking advantage of the "hand off the chest for two laps after takeoff" rule.

Another way this effect was used was when the arm could be extended during a pass. After drawing even with his opponent, the pilot would pull his arm in and take a step backwards to help things along. This same phenomenon is used in Sunday flying to great effect when doing loops downwind. After the engine quits, the pilot can whip and pull in on the bottom of the loop and then coast up to the top, putting enough energy in to keep the plane flying for long periods.

In all of the discussion to date, not enough attention has been paid to the subject of the load put on the engine and the setting. If the mechanic has tuned the engine to run its best at a given speed and load, and the pilot then changes conditions for which the setting is best, things can get worse rapidly. Flying in positions 1 and 2 does not change the load on the engine perceptibly, even though there is a slight change in line drag. Leading the aeroplane, coming into the wind, and having the flying radius reduced suddenly, all unload the engine and the reverse loads it up. In addition to these causes, increasing the "g" loading on the plane will increase its drag and also load up the engine. With light aeroplanes all of these loading-up effects are minimised and the high aspect ratios employed on most team racers help to reduce the drag increase effects.

Now those "g" loading effects will be touched on in a moment, but the worst effect is that from the pilot lagging the plane, perhaps because of being stuck behind a skilful, slower opponent, perhaps because of inexperience or lack of knowledge. This continual lap after lap running at lower airspeed leads to overheating and, if the engine doesn't cook up and stop, it may not restart and the aeroplane will eventually slow down and lose its speed advantage, thus nullifying a superior aeroplane. The only way to fight back is to lead the plane and run the risk of being fouled out or to adjust the engine before the race for a loaded-up condition which requires a richer and under-compressed setting and must give up laps and speed. To this, add the fact that a common mistake is to tune the aeroplane to run best while leading more (or lagging less) than normal flying circumstances will permit. In the 1970's this is a recognised mistake, even though it doesn't make for good practice times, and it is not made nearly so often as it was in the previous decade. As one can see, the pilot must make every effort to pass at the first opportunity. This will unload the engine and cool it down and, more importantly, establish in the jury's mind his superior speed and right to pass. If the pilot gets blocked for five laps or so and then in desperation decides to tow a little and pass, the jury will think his plane is matched in speed and he is "applying physical effort" to pass when he could not do so fairly.

Returning to the effect of a "g" loading, note that high flying demands far more lift from the wings than just the weight of the aeroplane. Continuous high flying requires wind lift to support some of the centrifugal force, for which see *Fig. 8*. Assuming the 100 mph pylon speed racer and the handle circling in a one-ft.-radius circle about the centre of rotation ("centre spot" as the F.A.I. Sporting Code calls it), the following calculations should illustrate the problem:

Handle against the chest held 4·50 ft. above ground level and aeroplane flown continuously at the minimum/maximum normal flying height (6·56 ft./9·84 ft.), the wing lift must be 1·5/2·3 times the weight. Only if the

All over for Heaton-Ross (U.K.) at the World Champs finals, a turn-in on take-off spelled disaster after a valiant effort. Opposite—the Dutch winner the Metkemeijer brothers with Enrico Flores who prepared the engine. Record times of 3:44 and 7:32·5 testify to their exceptional ability.

plane could be flown at 4·5 ft. altitude would the lift equal the weight, and this is against the rules.

Handle above head at 6·00 ft. above ground level and aeroplane flying at the maximum height permitted during passing (19·69 ft.), the lift must be 4·41 times weight. Very few people realise that flying at a constant altitude like this puts such a load on the aeroplane—no wonder wings flex!

This additional lift will certainly reduce the airspeed of the aircraft since the drag must be higher. However, since the flying radius is shortened, the effective speed or timed speed may not go down at all; for most high aspect ratio racers just the opposite may occur and high flying may pay off if you can get away with it.

Flying within the rules, however, flying at a constant three metres altitude compared with two metres shortens the radius less than one tenth of one per cent. The increased load for pulling a continuous 2·3 g's can hardly be worth it, so the best position is down low. Few juries disqualify or warn pilots for flying below the 2-metre limit and "it's done all the time" so this encourages a lot of really low flying. Normal flying isn't the problem. The question is, when passing—passing two at a time for instance—how high should one fly? The best solution is to time a few laps while flying high (six metres) and, if the speed is timed as increasing, then consider using the maximum height allowed during a pass. This reduces radius about 3·5 per cent. Also, the dive down to normal height or lower after the pass will help gain speed when passing the fastest people.

SECTION II
"Flying With Others"

So far, all of the things affecting speed that the pilot can contribute to have been discussed, but mainly as if the pilot were out there flying all by himself. In competition, the presence of others in the circle

won't change these facts, but it will change what the pilot has the opportunity to accomplish. The discussion of these problems is necessarily much more qualitative. It is impossible to estimate the speed loss due to getting your lines caught in the competition's hair, for instance.

Flying with other people presents a number of problems, not the least of which is passing, even when you have the faster aeroplane. The Soviet Union proposed a "hand off the chest for three laps" rule to provide a longer time in which to pass. Just how much faster you have to fly to pass while obeying the flying rules is an interesting thing. Consider two cases: (both aeroplanes flying at a constant speed), the faster aeroplane having to gain (a) ⅛ of a lap and (b) ¼ of a lap while covering no more than two laps. The tables below show the *fastest* opponent you can pass.

Pass in Two Laps

Laps gained	Your speed (mph) 90	100	110
⅛	84·4	93·8	103·1
¼	78·8	87·5	96·3

Pass in Three Laps

Laps gained	90	100	110
⅛	86·3	95·8	105·4
¼	82·5	91·7	100·8

As is plain to see, under present conditions and a strict interpretation of the rules you have to have a terrific speed margin to do any good. A 100 mph racer can't even squeak by a 94 mph racer in two laps. As we will soon see, blocking makes it even worse. Getting into the semis may depend on being lucky enough not to have to fly against a good slow team. That is one that won't retire, will fly for the best possible race outcome and makes rapid pits. The Russian proposal will help some, as you can see from the table above.

Even if you have the speed advantage necessary to pass, the presence of another pilot in the circle can take it away. Taking the simplest case first, one big problem is presented when one pilot occupies the centre, just twirling around on his heels. He is probably some gorilla who can also lean back with an alarming spinal curvature. Worst of all, he can't speak English so you can't tell him how you feel. Since the British rule proposal isn't yet formal, you can't fly with your lines over his shoulder unless you are taller than he is so, for practical purposes, the space he blocks out—space that your lines can't pass through and space you can't occupy—is approximately a rectangle 2 ft. by 1 ft.

Suppose he has a 95 mph plane and you have a 100 mph plane (when flying from a pylon, as usual). From our simple-minded catch-up

analysis above you won't gain ⅛ of a lap on him in two laps even if you both fly at your normal speeds undisturbed. Still, with five miles per hour on him you have to try a pass and hope you don't get fouled, maybe you can get it done in less than ⅛ of a lap. In this case the jury is not faulting him for standing. The blocker's profile is shaded in and his lines are shown in *Fig. 9*. Your plane is always toward the top of the page in *Fig. 9*. There are four views showing the conditions ½ lap, ¼ lap, ⅛ lap and even with him. Half a lap apart he has you pushed out a little so you do 97 and he does 94 because of increased flying radius. In all the other views his effective speed is 94. Note how yours is brought down the closer you get. The flying speed differences are calculated from *Fig. 6*.

By the time you get close enough to pass he has forced you into a large walking circle and all the speed differential is lost. Clearly, if the jury doesn't call him he will ruin your time and improve his own and this kind of conduct is the jury's first duty to stop. From the standpoint of jury psychology, what is crucial (as pointed out earlier) is to get behind him and whip if possible to pass him right away and establish in the jury's mind your superior speed and right to pass. If you get fouled on the first attempt you can always cool it and take your chance later.

Desirable Rule Changes

Every flying style affects speed to some extent and there is nothing either good or bad about any of them in the sense of being intrinsically unfair. What the rules should try for is to ensure that all contestants are limited to the *same* flying technique so it affects all models the same. What makes a good idea is that otherwise pilot height and physical aggressiveness will play a big role and will discourage many excellent teams from competition. The present rules and suggested modifications call for an impossible situation. First the handle, plane and "centre spot" should all line up. Excellent. With this rule all one has to do is keep the walking radius about constant and everything is equalised. Now the proposal to

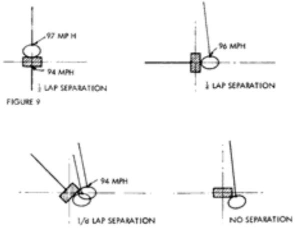


FIGURE 9

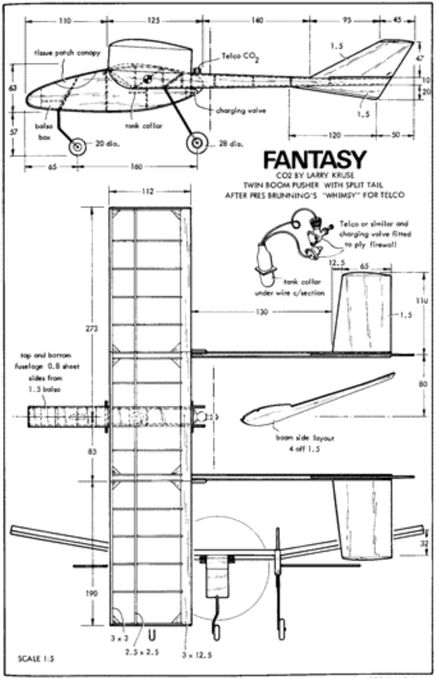
make the lines exit at right angles to the shoulders. The only way both of these things can happen is for the pilot to walk sideways. The *first* must is that one of these has to go. To ensure the centre is not occupied by other than those who are passing, I suggest that a 1-metre radius solid-colour circle be placed in the centre of the circle, possibly with some small protrusion so pilots could feel they were stepping on it. This will make it easy for the jury to ensure a constant walking radius and identify the orientation of the lines with respect to the centre spot (regardless of which rule is kept).

Second is that the passing rules must be rewritten. As it is, it is not possible for most contestants to pass without the jury winking at the rules. Clearly the Russian proposal of three laps is a must and just as clearly, however, I think the analysis showed that the line crossing prior to the pass must also be permitted so as not to cause a slow down and encourage blocking. If the pass is not complete in three laps after the lines are crossed the contestant should be fouled. He can count and uncross then if he is not successful.

The *third* thing is that flying height rules should be strictly enforced, particularly low flying. Low flying could be dangerous and either the height rules should be changed or fouls should be awarded for any low flying. In most contests that I have seen—both here and in Europe—the rule is completely ignored. Many teams practise flying for hundreds of laps at elevation of 5 ft. or so and they don't change when they compete. Rules should be enforced, rewritten so they can be enforced, or thrown out.

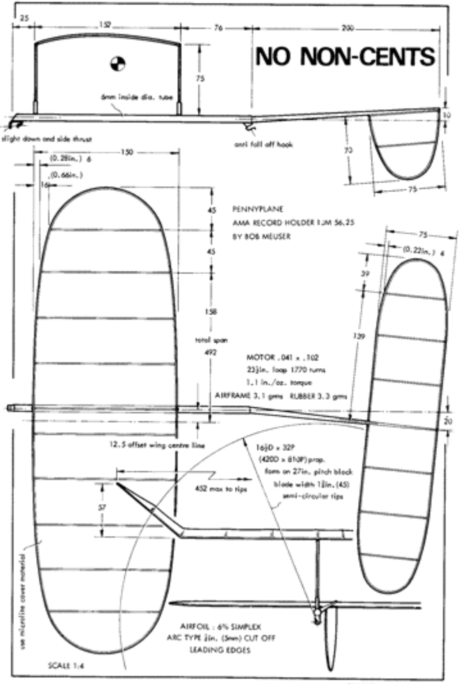
The *fourth* item is a little less clear, but it seems to me that unless taking off or landing the handle should always be on an axis passing vertically through the centre of the chest—that is a passing pilot could raise it above his head but only vertically. Together with this I would suggest a policy that all flyers be asked to fly with their hand at the highest position that is comfortable. This is only personal preference based on a minor safety potential and less up and down when passing as well as easier visibility for the jury. While landing and taking off the arm may be extended, the rules should make it clear that the extension is only permitted while the pilot is stooped over for others to pass. Once he's up to speed and ready to race, standing up and all that, the rules should be the same for all pilots.

Now the last point. The jury deserves to be free from intimidation and deserves some recognition. Most modellers will have at one time sworn at, berated, demeaned and scorned officials—and can't understand why they're not better. What is the jury's incentive? It would be good if the jury would be honoured and if they could be encouraged to be very strict. Perhaps team trials and National Championships would be a good place for this emphasis to begin. The jury should be permitted a warm-up heat to demonstrate to contestants how they will call races and how they have elected to communicate fouls. I would also like to see a critique of the officiating, by all contestants immediately after the Nats. and team trials. It shouldn't be too much work for the contestants or too much to ask of them and the only way to get any reasonable communication going.



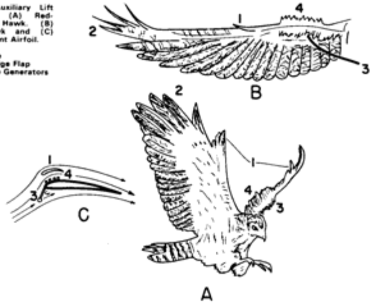
FLYING MODELS U.S.A.

NO NON-CENTS



NFFS FREE FLIGHT U.S.A.

Figure 1: Auxiliary Lift Devices on (A) Red-Shouldered Hawk, (B) Sparrow-Hawk and (C) Equivalent Airfoil.
1—Alula
2—Slotted Tip
3—Leading Edge Flap
4—Turbulence Generators



BIRD AERODYNAMICS

by Professor E. F. Blick (*University of Oklahoma, U.S.A.*)
(*From "Shell Aviation News"*)

DOWN THROUGH the ages, men have been fascinated by the flight of birds and have attempted to unlock the mystery of their flying mechanism. Da Vinci studied bird flight and in 1505 built the first known flying machine, a prone-piloted ornithopter. There is a rumour that the test pilot (one of da Vinci's household servants) broke his leg in the crash of the machine.

Da Vinci wrote that a bird supports itself by beating its wing down and propels itself by the action of its wing tip, which describes an alleged line from the front to the rear. He was almost completely wrong! Slow-motion pictures of bird flight have shown that its lift and thrust are considerably more complicated than da Vinci imagined. Otto Lilienthal, in the later part of the last century, imitated bird flight by gliding 800 yards in a glider with a curved airfoil section and a small stabilising tail. Lilienthal lost his life because he failed to understand that birds possess automatic stability, due to instinctive reflexes which change the shape of their wings and tails.

The rapid development of aerodynamics in this century has revealed many of the secrets of bird flight. Nevertheless there are still areas, such as flapping flight, that have not been completely unravelled.

The Wing

The wing of a bird is a marvel of engineering. A bird can fold its wings completely against its body, it can spread them out fully in gliding flight, and flap them when it needs thrust and lift. The flying apparatus of a red-shouldered hawk (*Buteo lineatus*) and a sparrow-hawk (*Falco sparverius*) is shown in *Fig. 1*, where four different auxiliary lift devices are seen:

1. Alula—This is a small group of feathers at the front edge of the wrist, where the inner and outer wings join. The bird can raise the alula to form a slot which keeps the airflow from separating or "stalling out" in this critical junction. The inner half of the wing is devoted primarily to producing lift, while the outer half does most of the flapping and produces the thrust.

2. Slotted Tip—The outer feathers (primaries) are slotted to form individual wings at the wing tip. As will be discussed later, these slotted tip feathers have a remarkable effect in reducing the induced drag (drag due to lift) of the bird by reducing the strength of the wing tip trailing vortex.

3. Leading Edge Flaps—Leading edge flaps increase the lift of the bird wing at large angles of attack by retarding flow separation. These have been developed also for aeroplane wings.

4. Turbulence Generators—On the upper surface of the bird wing, near the leading edge, are feathers that "pop up" at high angles of attack. These are similar to the vortex generators that have been added to some aeroplane wings like the Boeing 707. Wind tunnel tests at the University of Oklahoma on a stuffed quail showed that low pressure on the upper wing surface causes these feathers to pop up automatically at high angles of attack, when their effect is most needed. The tests indicated that even at a value of 35° the quail wing did not stall. When the quail feathers were artificially stiffened by hair spray the maximum lift was consistently less than natural feathers.

An equivalent man-made airfoil with three of the auxiliary lift devices is also shown.

Owls have unique devices on their wings to enable them to fly silently. The owl feather exhibits three peculiarities:

1. The upper surface has a padding of fine down. This apparently reduces the aerodynamic noise in flight and the friction noise as the feathers slide over one another.

2. The leading edge comb creates a boundary layer effect, which acts like vortex generators to increase lift by reducing flow separation and suppresses aerodynamic noise at the leading edge. A wind tunnel test at the University of Oklahoma on a small wooden wing equipped with straight pins to simulate the owl's leading edge comb showed that at low speeds (below 22 m.p.h.) this comb increased the lift. If one blows with the mouth on the leading edge of a comb-equipped owl feather at various angles of attack, and does the same to an ordinary feather, it will be obvious to the ear that less noise emanates from the owl feather.

3. The shaggy fringe on the trailing edge also acts as a noise suppressor.

Most birds produce a rustling noise as they fly. This noise is generated primarily by the turbulence, eddies and discontinuities along the wings. In contrast, the owl flies silently—a characteristic that, coupled with sharp vision and hearing, enables it to swoop down out of the dark and pounce upon small creatures.

Dr. Richard Kroeger of the University of Tennessee Space In-

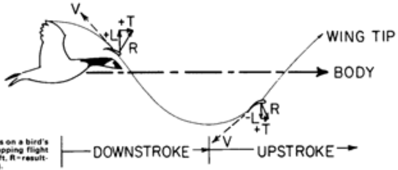


Figure 2: Forces on a bird's wing during flapping flight (T=thrust, L=lift, R=resultant).

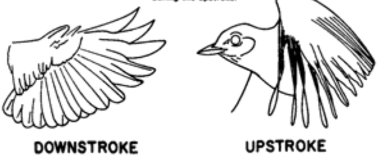
stitute has recently measured the noise generated by flying owls. He found that owls which had been sprayed with women's hair spray were much noisier. Apparently the hair spray hardened the downy upper surface and shaggy fringe on the trailing edge of the feathers.

Flapping and Propulsion

The most complex aspect of bird aerodynamics is flapping flight. As yet there is not an abundance of quantitative information upon it. This is not surprising when you consider that the wing twists and changes shape as it beats up and down, and in so doing both supports and propels the bird. The wing-beating frequency varies widely among birds; it is inversely proportional to bird weight, ranging from about 50 beats/second for one species of humming bird to around 1·3 beats/second for the pelican.

Fig. 2 shows the path traversed by a bird wing during forward flight, and the forces exerted upon it. What is surprising about the wing flapping is that forward thrust can be produced on both the upstroke and the downstroke. This is due to the favourable aeroelastic twist effect on the primary feathers. *Fig. 3* shows how the feathers are flattened for the downstroke and opened up like a venetian blind on the upstroke. The venetian blind effect on upstroke produces less negative lift than the positive

Figure 3: Venetian blind effect of flapping wing during the upstroke.



lift produced on downstroke, hence the net lift over the whole beat cycle is positive (up). The inner half of the wing is devoted almost entirely to giving lift and may beat up and down very little on some birds in leisurely flight. The outer half of the wing is primary the primary propeller of a bird.

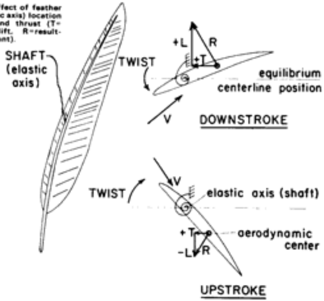
The favourable aeroelastic twist effect of the feathers and wing during flapping flight can be explained by the position of the shaft on a primary feather. The shaft is usually found within 25% of the primary feather leading edge, while all other feathers are symmetrical about the shaft. This shaft is also the elastic axis of the feather (the axis about which the feather will twist).

During the flapping motion the aerodynamic centre moves behind the elastic axis, hence the aerodynamic force during the downstroke twists the feather nose-down about the elastic axis (*Fig. 4*). The aerodynamic force now has a thrust component (upward). On the upstroke, the aerodynamic force rotates the feather about the elastic axis nose-up. The aerodynamic force still has a thrust component (forward) but a negative lift component (downward).

Another favourable effect of having the elastic axis well ahead of the aerodynamic centre is that the critical flutter velocity of the bird feather will be very high. For this reason one never observes catastrophic failure of bird wings due to flutter!

The hovering flight of humming birds is made possible by a shoulder joint of great rotational freedom. The wing forward stroke is conventional with leading edge forward, but on the backstroke the entire wing swivels about the root almost 180°.

Figure 4: Effect of feather shaft (elastic axis) location on twist and thrust (T=thrust, L=lift, R=resultant).



Soaring and Gliding

Flight on motionless wings, or soaring, was divided by Lord Rayleigh in 1883 into three categories: *gliding*—flight in which the path is not horizontal; *static soaring*—flight in an air mass having a vertical component of velocity; and *dynamic soaring*—flight in an air mass that is not uniform in velocity.

The conditions for a steady glide are exactly the same as for a man-made sailplane. Large values of the lift-to-drag ratio result in a smaller glide angle. During static soaring, the bird glides in the presence of rising masses of heated air that have an upward vertical velocity just equal to its sinking speed.

It is obvious that if a bird is proficient at soaring, it must have a high lift/drag ratio. The two main types of gliding and soaring birds, the land soarers and the sea soarers, each have a different method of achieving this.

The sea birds which are excellent soarers develop high lift/drag ratios because they have large aspect ratio (span divided by the average chord) wings. Aerodynamic theory has shown that induced drag coefficient (drag coefficient due to lift coefficient) is inversely proportional to the aspect ratio of a wing. Induced drag is caused, basically, by the two wing-tip vortices; if you place the two vortices far apart (by means of a high aspect ratio wing) then you reduce the induced drag. The albatross is a sea bird that is an excellent soarer and he has an aspect ratio of nearly 15—a very high value. The albatross takes off from long level beaches and soars over water, and hence has no worry of obstructions in operating his long slender wings.

Land soarers like vultures, eagles and hawks operate out of trees and shrubs, and off rocks, and so would have great difficulty if they had high aspect ratio wings. Hence land soarers are found with low aspect ratio wings. The condor only has an aspect ratio of about 6, yet he soars very efficiently. The paradox is evident. How can land soarers with low aspect ratio wings possess such excellent soaring ability, when aerodynamic theory states that a high aspect ratio is needed to reduce drag coefficient and produce high lift/drag ratio? The answer lies in the slotted wing tips found on land soarers as on a soaring eagle, and on a hawk.

The slotted wing tip reduces the strength of the tip vortex, and hence the induced drag. It consists of six or seven long slender primaries which, considered as individual airfoils, have a high aspect ratio. In addition, these pinion feathers are spread out vertically due to the air loads that bend them upward. As the pinions bend under the air load, stresses are set up to produce more and more curvature or camber in the feather. Such cambered feathers can produce more lift than flat sections. The leading pinion curves up more strongly than the second, the second curves up more than the third, and so on. They assume their proper curvature automatically due to their elastic deformation under the air loads, not by any direct control of the bird—it is automatic geometry control.

The upward curved pinions sweep the air outward away from the centre of the wing, thus preventing the air from sweeping it from the tip over the upper wing surface. In this respect the pinions may be likened to end plates on wings, which eliminate a proportion of the induced drag.

How good is a bird's drag compared with modern aircraft? The late Gus Raspet, who was the head of the Aerophysics Department at Mississippi State University, made some excellent drag measurements of buzzards by following them with his sailplane. *Fig. 5* shows some of the results obtained by Raspet. The black buzzard's skin friction coefficient is 30% higher than that of the laminar plate (the lowest possible!), whereas one of the best man-made flying machines, a sailplane, possesses a drag coefficient no less than 330% higher than the laminar plate flow. This gives some validity to the speculation that birds possess some type of boundary layer control. Such boundary layer control may be associated with the compliancy or possibly the porosity of their feathers.

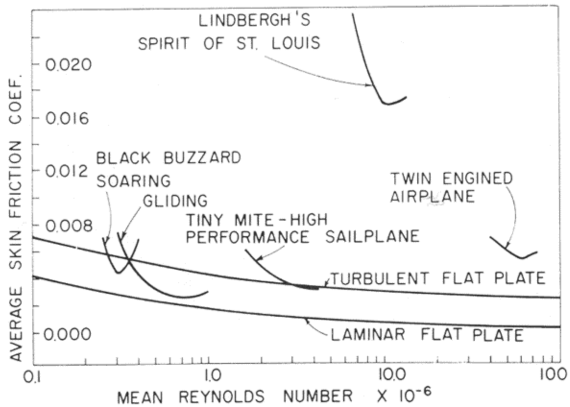
From the results of feather compliancy measurements made at the University of Oklahoma, there appears to be an increase in the stiffness of the feathers as the flight speed of the bird increases.

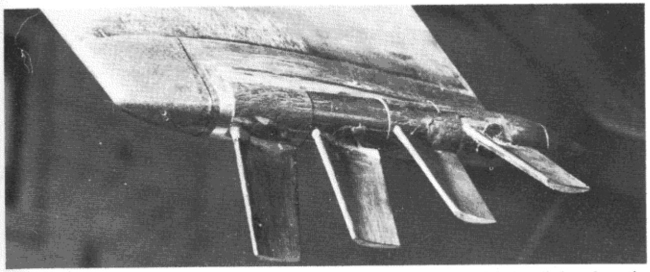
Flight Control

The control of pitch by a bird can be effected in two ways—by movement of the tail up, down, or sidewise, and also by forward or backward movements of the wing. At low speed the wings are swept forward. At high speeds, the tips are swept back by bending the wrist of the wing. This moves the centre of pressure of the wing farther back, which tends to give a nose-down pitching moment and trim for higher speeds has been achieved.

We have only scratched the surface of the complexities of bird aerodynamics here. There is still much the aerodynamicist does not know or understand about them. Fortunately this does not deter baby birds, since almost all of them can fly the first time they jump or are pushed by their mothers out of their nest!

Figure 5: Skin friction variation with Reynolds Number (from 'Biophysics of Bird Flight', *Science*, 22 July 1960, Vol. 132, No. 3421, p. 197, August Raspet).





Wind tunnel model experiment at Cranfield Institute of Technology where wing tip sails have been the subject of considerable study.

Applications

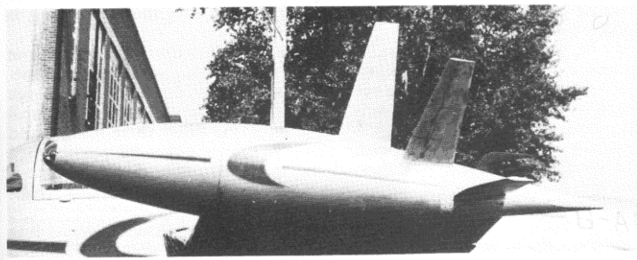
One possible application of bird aerodynamics might be to the problem of the tornado-like turbulent vortices trailing the wings of jumbo jets. These invisible wing-tip vortices may spiral back for miles. A small 'plane passing through the trailing vortices (or wake turbulence as it is more commonly called) can experience a violent bump and possibly go out of control in a spin and crash.

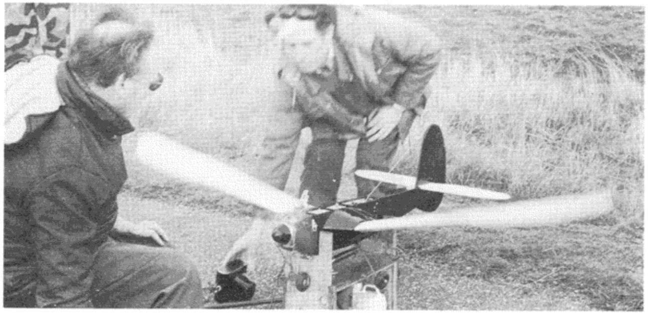
Tests at NASA's Edwards Flight Test Centre showed that a twin-engined Learjet was rolled on its back when it was caught in the tip vortices 3·7 miles behind a C-5 transport landing with flaps down. Between 1964 and 1969, at least 98 accidents related to trailing tip vortices took the lives of 20 people and injured 54.

What can be done to eliminate or at least reduce trailing tip vortices? At the University of Oklahoma we are investigating the possibility of applying the concept of slotted-flexible wing tips found on hawks, eagles and buzzards to aircraft wings.

If a successful wing tip of this type can be developed it should reduce the accident hazard due to wake turbulence, decrease take-off and landing separation times at crowded airports and, quite possibly, provide a reduction in the induced drag of the aircraft.

Airborne tests on the Cranfield Morane–Saulnier Paris jet include this set of three wing tip sails on the tip-tank.





John Drake (left) assisted by Roy Sturman of Autogyro fame. The wing is beating at three beats to the second!! Exposure 1/25 second. Blurred wing illustrates the high flapping rate. There is no need to hold fuselage, the characteristic St. Vitus' Dance of most ornithopters has been overcome by articulating the wing.

AN EXPERIMENTAL R/C ORNITHOPTER

by John Drake

THIS MODEL is a direct result of the competition promoted in the December 1972 issue of *Aeromodeller*. It is the latest in a series varying from small rubber driven and CO_2-operated models to a large 10 cc powered 8 ft. span. All had the same articulated wing movement, the main variation being in the design of the mechanism and structure of the wings.

The success rate of these models was very low, by which is meant only one rubber-powered model flew out of at least six models! The non-flying attempts, nevertheless, were all very educational in the sense that they taught as much about what *couldn't* be done, as *could*!

For instance, early mechanisms were all buried within the wings, which made them difficult to construct, and the mechanisms were generally not stiff enough *i.e.* the shafts used for actuating the outer wing tips deflected and twisted when under load. Also, bearings seized up. All this resulted in undesirable wing movements. That is why the latest wing is operated by external cables.

One of the early lessons learned was that it is most difficult, if not impossible, to launch an ornithopter from rest by wing movements alone.

This can be said with a certain degree of confidence, because large birds, like swans, have great difficulty in getting airborne. As many will have noticed, swans have to paddle their feet to assist their wings, and generally have to make a supreme physical effort, using all possible leg and wing movements to get up to flying speed. Once up to flying speed, and a foot or so above the water, they are then able to use the full stroke and power of their wings to climb away from the water.

This was considered at some length, even to the extent of providing a drive to the undercarriage wheels, and retracting a very long legged undercarriage. The long undercarriage would be necessary to lift the wings clear of the ground, when the wings are at the bottom of their stroke. Problems in this area, are mind boggling, and with the added difficulties associated with the wing movement, it was essential to think of something far less complicated.

After much searching, a propeller was used to get the model airborne. Using a propeller has the advantage of allowing the undercarriage to be kept short, and hence there will be no need for a retract system.

As the model is purely a research vehicle to find out what wing movements are necessary to produce thrust and lift while airborne, use of a propeller would not be cheating too much. In any case a way of stopping the propeller was devised and the drive transferred to the wings whilst in flight, using the fourth servo of a 4 function radio control unit. In this way any spectators could be convinced, that if the machine continued to remain airborne, the flapping wings *must* be producing a modicum of thrust.

A final feature of the wing flapping mechanism was to devise a means of returning the wing to the glide position, which only occurs at one point in the complete wing-beat cycle.

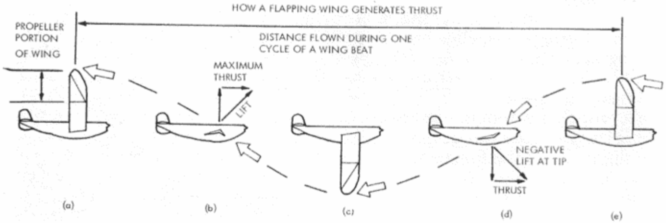
It is necessary to provide this feature, for without it, there could never be a guarantee that the wings were in the correct position for a glide, and return to propeller power for subsequent landing.

To date, this aspect of the wing flapping mechanism has functioned satisfactorily during ground trials, and it has been tried twice whilst airborne with the wing subjected to flight loads. The most uncertain aspect of this mechanism is the reliability of the engine.

Should the sudden shock of the wing flapping stall the engine, there is no way of returning the wing to the glide position. The prospect of flying the model with a wing in an exaggerated anhedral position fills one with horror!

The model first made one flight in the rigid mode and was airborne for about three minutes, just enough to prove that it would fly by means of a propeller. At least it is known that the wing mechanism and structure can take the air loads and that the wing leading edges doesn't twist uncontrollably. In August 1978, the power was transferred from propeller

Two pioneers, left, the doyen of British radio controlled modelling Howard Boys and right, John Drake the originator of home built helicopters and now ... the ornithopter seen at an Aeromodeller rally, Old Warden.



These five sketches show the wing tip, at the top, middle and bottom of its beat during one cycle. The dotted line traces the path of the wing tip during this cycle. The wide arrows show the angle at which the air stream apparently meets the wing tip at each instant.

The leading edge of the propeller portion of the wing is caused to move up and down, synchronised with the wing position so as to allow the airstream to meet the leading edge cleanly. Strange as it may seem, the mere action of oscillating a wing up and down whilst moving forward, actually produces thrust by virtue of the fact that lift is always at right angles to the airstream. So that in position (b) the lift is angled forward giving a resulting thrust. Thrust is generated between position (a) to (c) reaching a maximum at position (b). There is no thrust at (a) and (c), but there is a small amount of forward thrust at (d), provided a small amount of negative lift is tolerated on the outer portion of the propeller.

The peak velocity of the wing tip during the down beat must be at least $\frac{1}{3}$ of the forward velocity for there to be any useful thrust to keep the model airborne. The flapping rate of three beats a second is the predicted requirement to fly the model.

to wings at 200 ft. altitude and the immediate result was a fast roll! Fail safe return of the wings to glide mode worked and a safe landing resulted. So far so good!

MODEL SPECIFICATION

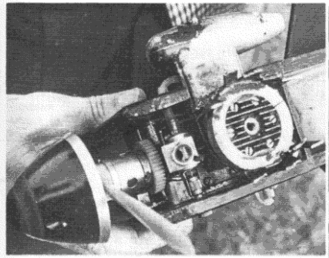
Engine: Merco 29 with a homemade heat sink to keep the engine cool when the propeller stops and the engine is working hard flapping the wings.

Wing span: 68 inches.

Weight: 6 lb.

Construction: Very conventional, sheet fuselage as on modern power models. Tricycle undercarriage.

Wings: Built up, using ribs and spar etc. The wing is covered with Solarfilm. A symmetrical section was chosen to overcome difficult geometric problems around the pivot points on the wings. Each half of the wings is made up of three hinged sections, all driven in the correct phases, one to the other to provide the maximum thrust during the down stroke, and to minimise the reverse thrust on the up stroke.



DRAKE ORNITHOPTER DETAIL

Above, the power unit with clutch drive to propeller and heat sink on cylinder for cooling when drive is disengaged from the prop. Underside view (below) reveals the gear drive shaft which activates the flapping mechanism through another gear box hidden in centre section. The clutch is simple and effective.

SEQUENCE OF WING FLAP

Right: a five-stage sequence of wing activation. Top: the wing in the "fail safe" glide position.

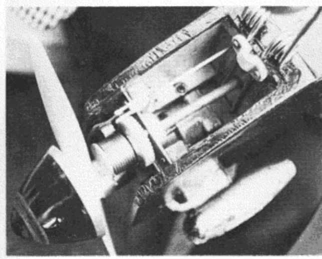
Next: the wing halfway through its downbeat.

Third photo shows the wing at the bottom of its down stroke.

In four the inner section of the wing is in advance of the outer tip (the propelling part) on the up stroke.

At bottom, the inner section of the wing has reached the glide position while the propelling section has still to move upward.

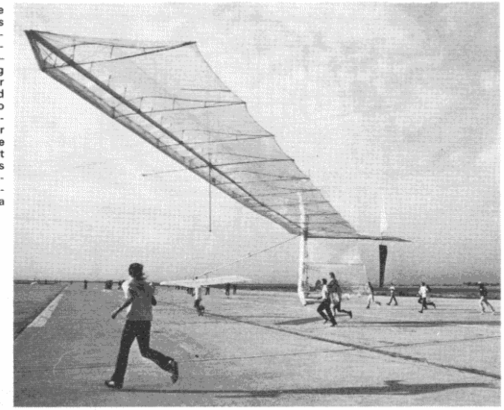
These photos were taken using the Editor's motorised camera during a demo drive by using a motor starter. Draughtsman Pat Lloyd who prepares the *Annual* drawings, is holding the fuselage.



"That new member's walking away with the ornithopter event."

John Drake contemplates the next move—a few heart-stopping moments before the fail-safe device held the wings to glide position were enough to make all the effort worthwhile—on with the experiment!

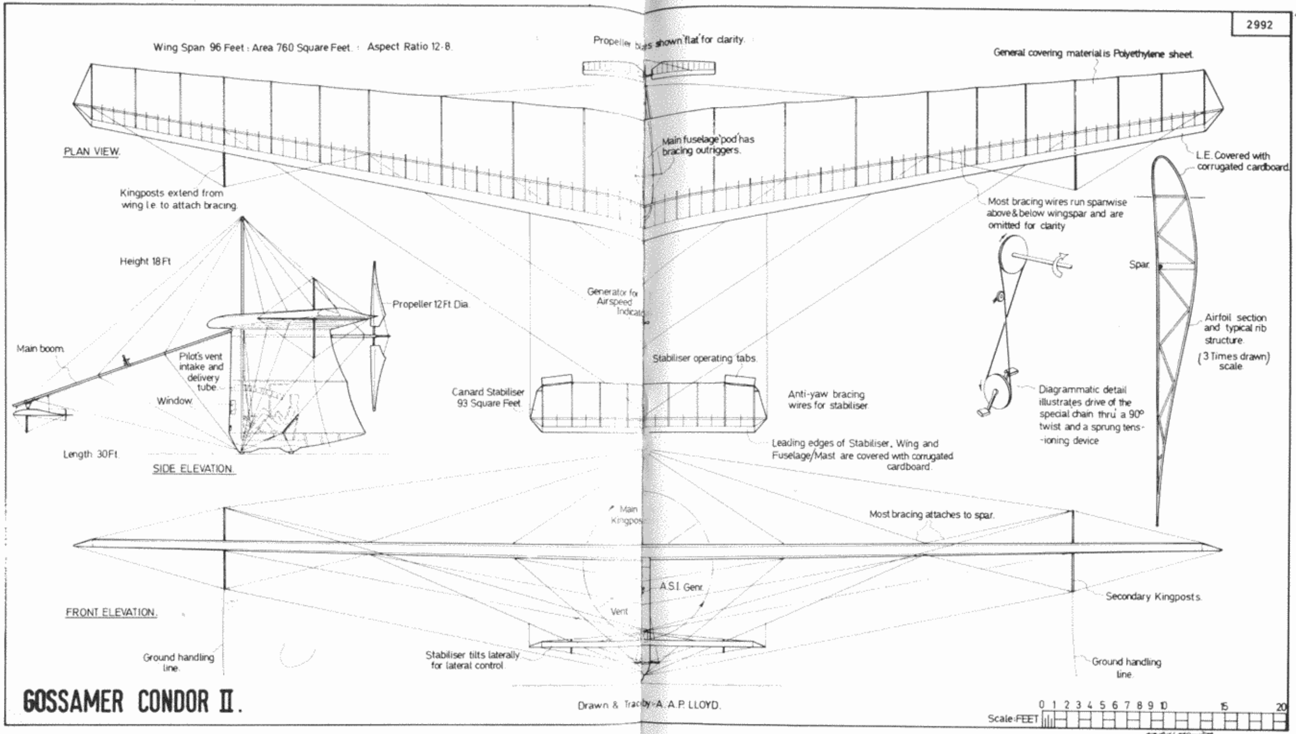
Monika Lake (18) one of the many lady pilots of the "Gossamer Condor" (including a handsome grandmother—Mrs. Oldershaw) flying at Shafter, October 1977. Slow airspeed enables runners to assist at critical take-off stage. Single spar has been called the "longest beer can yet made". Don Dwiggens photo. Paul MacCready's 1978 Gossamer Albatross has a narrower wing.

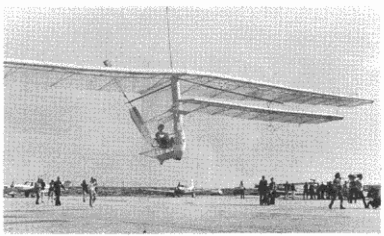


PROGRESS WITH MAN POWERED FLIGHT

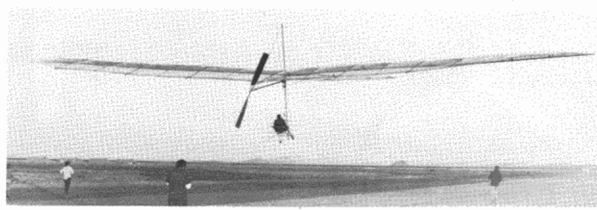
When Bryan Allen completed the famous figure of eight course to win the £50,000 Kremer prize on August 23rd, 1977, he proved himself to be an exceptional athlete. For in the intervening year, despite other generous prize offers by Henry Kremer, no other pilot has repeated the achievement, flown for three minutes or completed the less strenuous "Slalom" course. It took 7:27·5 to make the winning flight at an average speed little over 10 m.p.h. Other machines have flown in 1978. "Toucan" was rebuilt, tested over short hops of up to 160 metres before its retirement to the Shuttleworth collection and in Japan, the "Ibis" completed an 1100 metre first ever flight in 2:15 with Hiroshi Turui at the pedals.

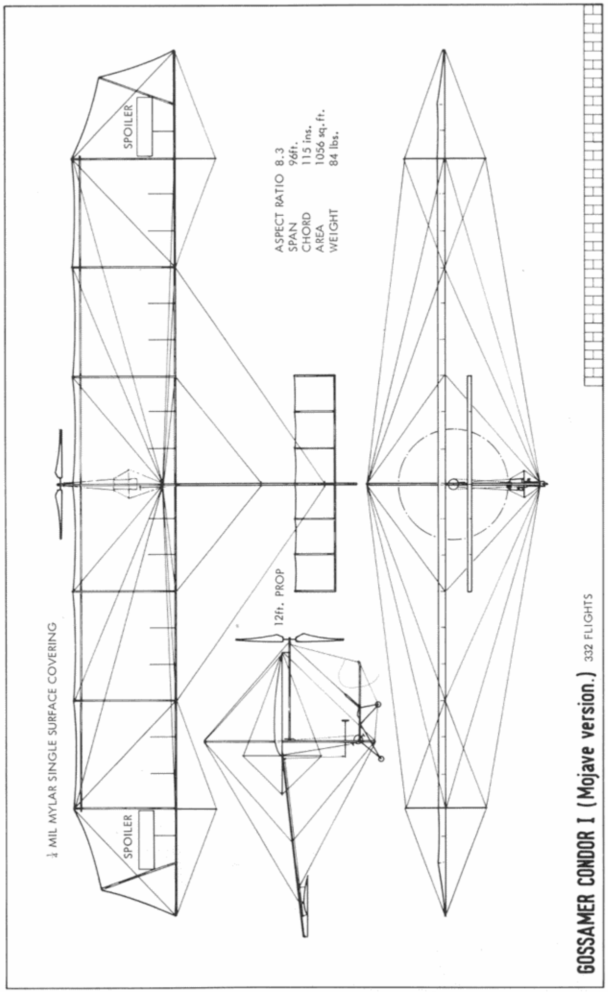
Tip sails characterise the latest Nihon University MPA. Called "Ibis" it obviously derives from the successful "Stork" with shorter span and length and though in the same weight category (75 lb.) as the "Condor", it has little more than one quarter of the wing area. 67 ft. 1½ in. span includes near vertical winglets, an innovation to reduce induced drag. In the U.K. and U.S.A. there are other new ideas centred on side-by-side linked span machines, the first of which is Admiral Nick Goodhart's "Newbury Man Flyer". The ultimate challenge to cross the English Channel is a stimulating target coupled with the largest prize in aviation history of £100,000.





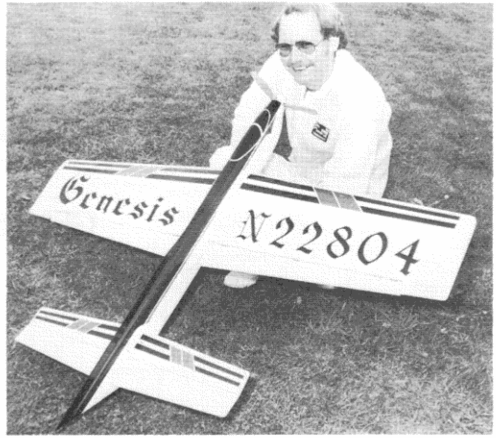
Bryan Allen rides to victory in the "Condor" (left), the tilting foreplane guides the ulta-light aeroplane around the elusive figure-of-eight course. At right, the first "Condor" was lighter still, had single surface wings and no fairing around the pilot. It made many flights at Mojave with Gregg Miller at the pedals, but use of the Lissaman aerofoils in the second version transformed its performance. See drawings on next page. Don Dwiggens photos.





GOSSAMER CONDOR I (Mojave version.) 332 FLIGHTS

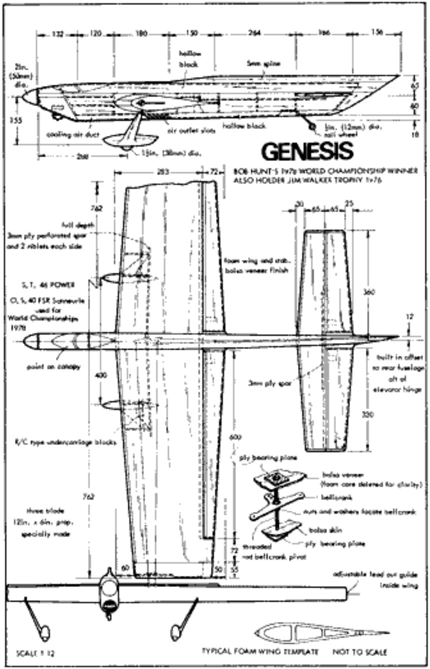
1976 and 1978 WORLD CONTROL-LINE STUNT CHAMPS



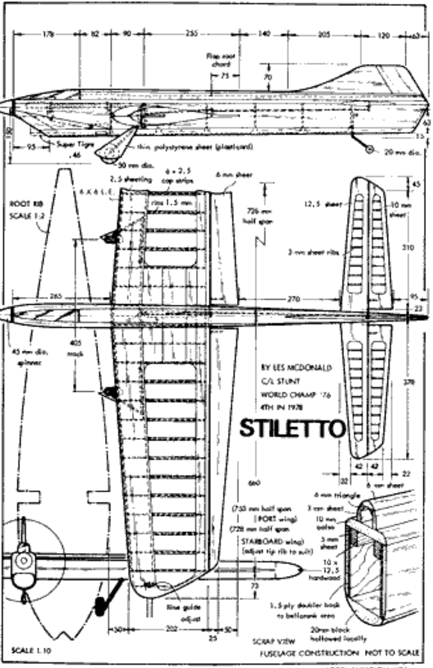
Bob Hunt, 1978 control line champ at Woodvale with his foam wing "Genesis" and its O.S. 40FSR Schnuerle-ported motor which drives a three-blade prop. Bob only narrowly defeated fellow countryman Al Rabe in one of the closest contests ever known.

The three U.S.A. team members and ex-champ MacDonald filled four of the first five places in the 1978 finals at Woodvale. Their superb display was only rivalled by Compostella (Italy), Billon (France) and Hara (Japan) who now form the élite in control line aerobatics. Beautifully finished, and having the sleek lines now customary on American stunt models, these designs will influence world thinking. In fact many of the supporting competitors also flew "Genesis" or "Stiletto" derivations. This meeting also saw the first serious use of foam wing structures, which happen to be Bob Hunt's speciality. Details of the differing structures are evident in the drawings which follow on the next pages.

Les MacDonald, 1976 Champion at Utrecht, prefers built up wing and tail structures, and in this latest model had added ribs and discarded the leading edge sheeting. Les was fourth in 1978, just ahead of another ex-champ, Bob Gieseke (1974).



FLYING MODELS U.S.A.



MODEL AVIATION USA

LIVING WITH HISTORY

by Frank Zaic

From a busy lifetime of experiences, the maestro reminisces ...

I MET Kurt Hammerstein, by chance, at the Greyhound Bus Station in Buffalo in June 1937. This happened when I found someone else just as anxious as I to get the front seat on the bus by arriving early at the boarding gate. But it seems that Kurt was even more anxious than I, as I found him at the gate ahead of me. There is something about the front seat that makes an early arrival at the station worthwhile, especially for the night ride. At night, the front seat is the first seat on a cruise through the milky way and the galaxies, with stars and comets rushing towards you, and distant pinpoints of lights coming slowly towards you.

As soon as we were outside of Buffalo, riding at a steady, rhythmical pace through the dark countryside, Kurt and I began exchanging our personal histories and experiences. Yes, we did get the front seat to the right of the driver, with Kurt by the window, and we were young enough to start talking to each other as a matter of fact. He told me he was German, going on seventeen, and that he was on a straight-through trip from Pasadena, California, to New York City. In Pasadena he had attended Pasadena High School. I could see that he must have been a popular boy; he was tall for his age, with clear blue eyes and a spray of blond hair. He had expected to stay in school another year, but his family in Germany had called him back.

At the bus stops, while other passengers drank hot coffee to offset the chilly night air, Kurt and I had ice cream. Oh, we were very scientific about it. We knew that ice cream had lots more calories than coffee. Just give the ice cream a chance to get into our system, and we would feel much warmer than folks who had hot coffee with its short hot blush. We had ice cream at every stop, even at 5 a.m. when the eastern horizon had just a tinge of blue. I can still hear Kurt crunching on the cone, and see the contented look on his face as he made the ice cream disappear. I had practically no money, but he had less. So he was my guest.

As the bus rolled towards New York, we kept on talking. He told me his father was an officer in the German Army, and that his family lived in the suburbs of Berlin. I mentioned that I would be going to Europe in a few days, and that if I was near, or in Berlin, I would look him up. Then he mentioned that he would like to stay in New York for a while until his ship sailed, but he knew no one there. The nearest friend of the family was in Connecticut. So it was only natural to offer him the use of my rooms while I was away, and it was arranged he would see his friends in Connecticut and then go back to New York and use my rooms. When we arrived in New York, after being together almost 12 hours, we exchanged addresses, and then parted, never to see each other again.

As many travellers have learned, one can never tell what will happen on a journey, especially if one competes in International Model Aeroplane Meets. It just so happened that we had such a Meet in England in 1937, and I was a member of the American team. One of the twelve countries that took part was Germany. During the Meet, the German team manager invited us to go to their National Contest in Germany in August. Since I was able to stay in Europe until then, I took advantage of this offer, as did five Englishmen.

The visit to the German National Model Aeroplane Contest and the subsequent visits to their aeronautical educational schools, is a story in itself, but at present it has only academic value. After the Englishmen left, I stayed in Berlin for almost another week, still a guest of the Aero Club under personal attention of a tall, party-uniformed Major.

Towards the end of my stay in Berlin, I asked him if it would be possible to telephone a family whose son I had met in New York. I showed him the name and address Kurt had given me. As soon as he looked at the name, his head snapped towards me, and he said: "Do you know Hammerstein?" I said yes, and then explained the New York situation. Although Kurt had told me his father was an officer, he did not tell me that he was "General Hammerstein".

Well, after that, my Major was all puffed up with importance and he always had that perplexed look on his face when he looked at me, just as though he was asking himself how was it possible that I knew Hammersteins while he did not. He called Hammersteins and found out that Kurt had not yet come home. Yes, they knew me from Kurt's letters, and could I come out to them for a visit. Could I come for a visit? I sure could!

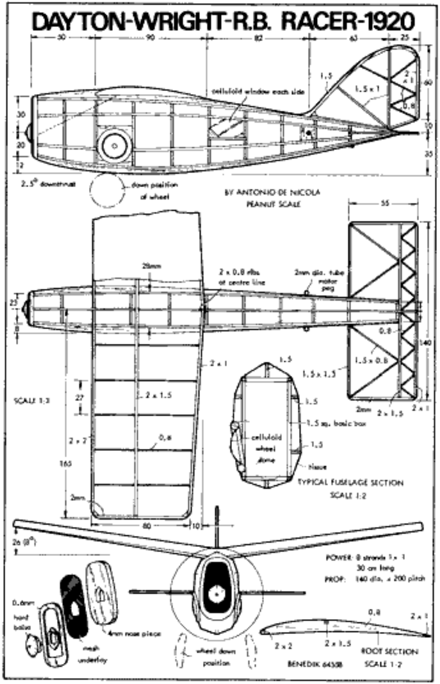
My Major had no trouble finding transportation for me. And what transportation! A Mercedes-Benz limousine with a uniformed chauffeur and his partner, and with flags on each front bumper. And there I was, sitting nonchalantly in the back seat with my Major, just as if I had been used to this kind of service all my life. I mean, for young folks, that was living!

Kurt's home was, naturally, in the best part of Berlin's suburban area. It was an estate with ivy-covered walls and a grand formal garden. Unfortunately, now that I look back, his mother and father were not home, but his older sister and younger brothers made me feel welcome. She spoke school English and we were able to keep up a conversation for almost two hours. They showed me their home, but I only remember the room in which the walls were covered with heads of mountain sheep shot by the General in the Alps. Later on we had coffee and cake in the garden. All this while my Major and Mercedes transportation were awaiting my pleasure.

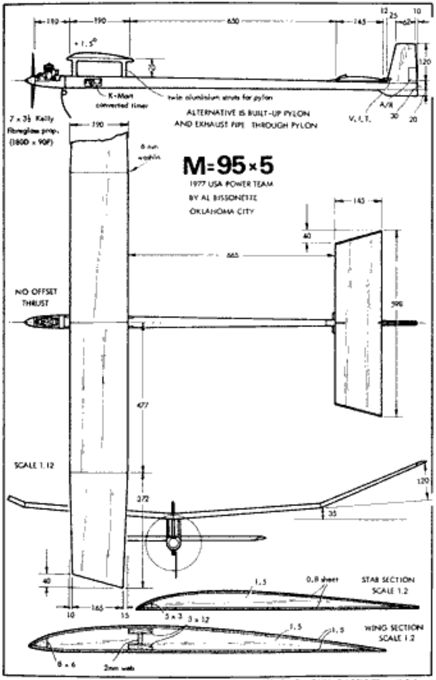
Now, this experience, rich as it was with gratifying incidents, would be just one small conversation piece about something that occurred while travelling and moving with the tide, if it were not for one special exception; the fact that Kurt's father was General Hammerstein.

In 1956 I was glancing through a book on espionage, I think it was the *Silken Cord*, when I came to the chapter that described the attempt on Hitler's life. At the end of this chapter was a list of persons who were involved in the plot and who were later on executed. My eyes were sweeping down the list when my heart made a sharp jump. There, on this historic list, was the name "General Hammerstein".

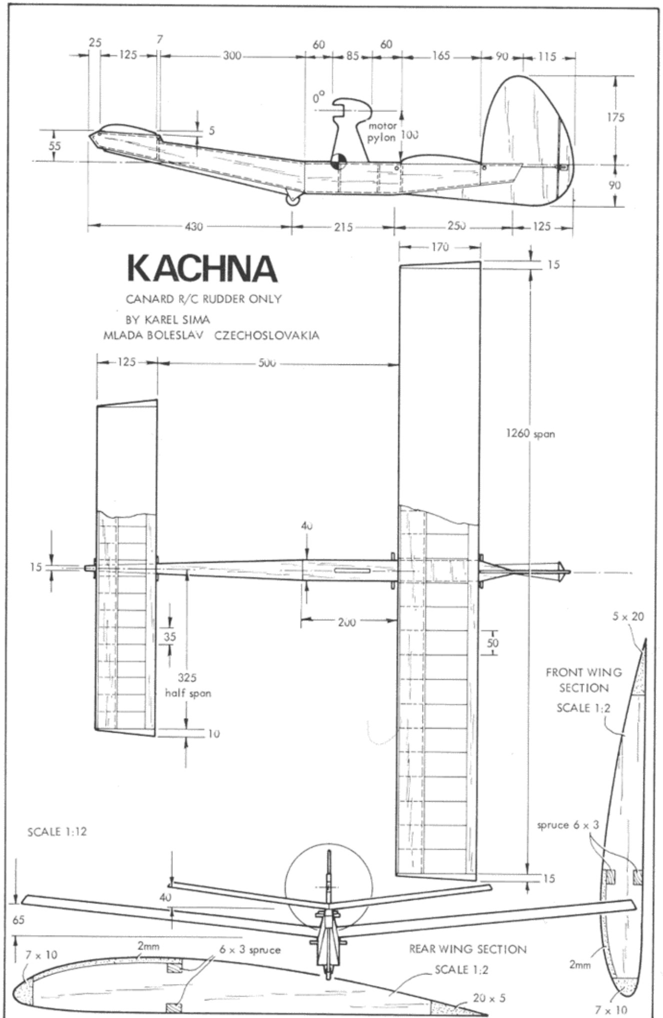
Sometimes I wonder what happened to Kurt.



MODELLISTICA ITALY



MAGNIFICENT MOUNTAINMEN DENVER U.S.A.



MODELAR CZECHOSLOVAKIA

Liverpool D.M.A.S. uplift their 747 for flight at Woodvale.

THE ART OF THINKING BIG

by Lee Taylor

(From "Model Aviation", U.S.A.)

AMONG MANY pipe-dreams modellers have always drooled over are the big, beautiful scale models. Picture, for example, a one-third life-size *Stearman* sailing overhead. Sunlight sparkles off the huge wings and the steadily-spinning prop. The big biplane pulls up and gracefully completes a loop. It rolls majestically. A dream? Not any longer. The day of the big model has finally arrived.

There were always a few people who felt they had to achieve these dreams at any cost. Bill Bertrand often heard comments that his $\frac{1}{4}$-scale *Fokker D-VII* flights were the highlights of the U.S.A. Nats. Ed Morgan in Las Vegas was flying a nine-foot *J-3 Cub* with an engine made out of two McCoy 60's, when most of us thought a plane with a ·45 was a monster.

Everyone was enthralled with these big birds, but they were far out of reach for the average modeller. The machine work to modify engines, the insurmountable task of designing without anything to go on as to structural technique, flight dynamic requirements, usable materials, not to mention the poor reliability of radios at the time, were too much for all but supermen.

All that is changed now. Nine-foot J-3's. *Champs*. *Citabrias*, are becoming almost commonplace and far-out designs are popping up all over. The catalyst for this explosion had been the arrival on the market of really big, bolt-in engines that require no more work than any other model engine to get to run, and have the lifting power to cope.

Our biggest problem has always been lack of power. Regardless of what some people have preached, a nine-foot plane with a ·60 for power, does not have generally acceptable performance. It can be done, but it isn't good enough for everyday fun. Even the big O.S. ·80 struggled with most of these models.

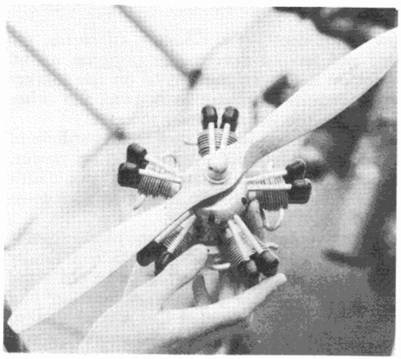
Then, about two years ago, things started to fall into place. Radios developed to the point that they were no longer a limiting factor. Really good builders and pilots were becoming bored with the same old sized models that everyone has been building for years. Competition had developed to the point that only the super-dedicated had any chance of winning. People started remembering those sparkling daydreams and asking themselves "Why not?"

On this scene appeared Canadian Ron Shettler quietly saying he was marketing a 2·0 cu.in. converted chain-saw engine, especially adapted to model use, to be called the *Quadra*. To say that Ron was a visionary would not have stretched the point. Most sneered when the idea was mentioned. But a few people tried the Quadra, and liked it, and the big plane movement got off the ground. Manufacturers actually started making products intended for these monsters. Suddenly, Quarter-Scale, and bigger had arrived commercially. New, very good engines made their appearance. They were not, of course, the first in the field. Chain-saw motors have been used by Mick Charles and Jim Davies in large-scale models for film and publicity work in the U.K., but there was a restraint on further developments.

The real announcement of the birth of Quarter-Scale came last year at Las Vegas, when Eddie Morgan brought the dream of his lifetime to fruition with the first annual Quarter-Scale National Fly-In. With little advertising, 32 monster models and over 100 modellers showed up to form the Quarter-Scale Association of America.

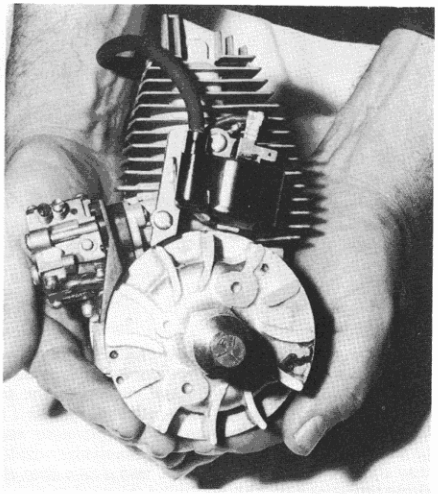
Most appealing is the diversity of engines that are becoming available. They range all the way from some of the newer "little" ·60's that are earning the reputation for being excellent for the lighter biggies, on up through ·80's, ·90's, 1·4's, 1·5's and, finally, Shettler's big 2·0 Quadra. Of course they are not exactly cheap. Most follow the standard glow engine concept, some are converted industrial engines, and some, like the Quadra, retain the ignition of such industrial engines. Several manufacturers have come out with reduction drives to allow the standard (and proven) ·60's to swing a much bigger prop. Large propellers are available at quite reasonable prices. Wheels, hardware, and new accessory products are showing up so fast it is hard to keep up with just exactly what is available. In general, monster scale has arrived.

Of course, being the "new baby" that it is, the man who is about to become a first-time "parent" is faced with a whole new set of bewildering problems. Many, if not most, of the techniques he has learned in the past



Glen Hargraves' five-cylinder four stroke radial is made in Ireland and has a high demand. It is more a novelty than a practical power unit for big models but can fly a moderate weight model.

When the Editor visited Ron Shettler in August '76 this first Quadra was demo'd. Since then many thousands of the simple chainsaw two-stroke have been put to good use in models around the world and fulfilled the dream of big-stuff flying.

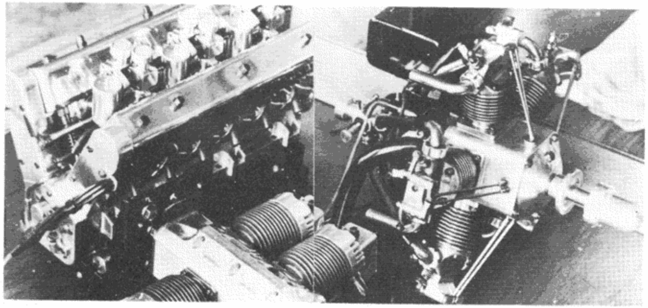


need to be modified, or even forgotten, and new ones learned. "*What materials do I use?*" "*What is strong enough?*" "*Can I find a cheaper way of doing it?*" "*What engine will work best with the model I want?*" "*My God! This turkey is going to weigh 25 pounds!*" Once the serious work begins, the almost unanimous reaction is a panicky call for help.

While there is no way that any one person can take it upon himself to answer the questions that everyone has concerning models of this size, I will attempt to describe what I think is a good way to go. I see two major problems that almost everyone has faced when starting these big birds. First, of course, is what will work when building. Second, and very important, is pilot ability. These big birds fly very, very well, but they also fly quite differently from "regular" models, and a little thought and practice beforehand will save some anxious moments in the air.

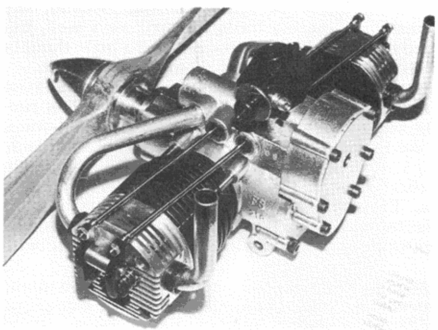
If you can stand waiting just a little while before starting your big bird, I have a method that will save you some grief in the long run. Buy a Sig J-3 Cub kit, the long wing original, not Hazel's clipped-wing, and build it. Mentally make a nine-footer out of it, take your time, study the construction as you go, and think of various ways that you might change things here and there to strengthen it. Think in terms of thin plywood instead of balsa. The Cub was designed many years ago. Its construction is very similar to what is used on most of the biggies, and you can visualise many of the problem areas that might crop up later with your biggie.

For example, if you look closely at the kit and analyse it, you might see that the corner longerons are balsa, and are exposed to bumps or bangs. Wouldn't those be better if made from small hardwood dowel, so

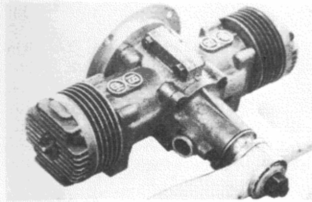


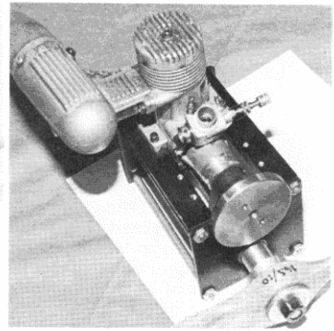
that they might not break so easily? And what about that wing strut attachment? Sure, it was good enough when this plane flew virtually free flight with an ·09, but will it stand up to the stresses of a modern-day engine pulling it through snap rolls and spins? That cabin structure looks flimsy: all those windows make for very little structure to hold the wing to the fuselage. Dowels spliced into all the window posts, running all the way up into the wing root area, and down into the fuselage, to tie everything together will add immeasurably to the strength. The tubing structure in the windshield. It can be made out of wire, running down deep into the corners to help tie the front cabin together, and helping a lot in the structural rigidity of the forward section.

A quick reminder here. As you are doing this experimental building with the Piper J-3, be sure mentally to blow it up to monster size. Get used to thinking about what kind of forces and strengths you shortly will be dealing with. Remember, you will no longer be dealing with just fairly moderate forces. The engines you will use put out fearsome power. They



Top, the superb engines of Wim van der Hoek (Netherlands), the 54 cc Vee-twelve, 26 cc flat four and 25 cc five-cylinder radial—all working four strokes. Left, the Swedish Damo 19 cc four stroke twin produced commercially and now appearing all over the world.





Mick Reeves (World Scale Champ '78) joined two HP61 cylinders for this 20 cc twin. Right, is the Master Climb Products 2:1 drive for 60 to 90 engines claiming 10 lb. thrust.

are big, heavy, and when you get that much metal charging up and down in a cylinder, swinging 16, 18 or 20 in. props, the vibrations and stresses are no longer something that simple balsa wood and model cement can handle! You have to start thinking about how your structure can be designed to help out and, for once, you aren't going to be worrying that much about weight, at least in the nose.

Cover the model with silk or double-covered Modelspan. Get used to the idea of building and covering a model again, rather than just wrapping it up like a package in plastic wrap. Many of the bigger birds, and the little J-3 also, are designed with the covering in mind to add structural strength and rigidity. The plastic films do not do this, and if you use them on the biggie, you are going to lose a great deal of the strength that was designed into the model.

As you are doing the covering and painting, be aware of what you are doing. This is the point where you can really pile on the pounds if you become sloppy. The point here is to get a good finish with the bare minimum number of coats. Start with the structure very well finished, without bumps or dents which you need to fill later with body putty. Put the covering on smoothly and evenly, taking time to pull out wrinkles and smooth out all seams. A little extra time here will save hours of sanding and filling and, more importantly, pounds of weight. What is a brush stroke on this Cub model will be a bottle of paint on the biggie! Practise doing things right the first time, so that you don't have to worry about repairing the goofs later.

Plan on powering this plane with a good ·19 or ·25. Do not use more power than this. If you do, you will negate many of the training aspects. Use a full 4-channel radio, with normal controls. Stick in a parachute drop for fun.

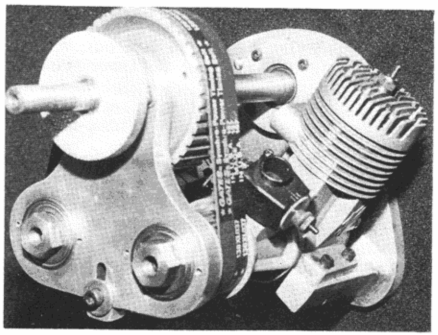
Now comes the fun part, but some of the hardest work. You must learn to fly this beast. Remember that stick that controls the rudder? Yeah, the one that you use for steering on the ground, but have always forgotten about once in the air. From now on you cannot forget about it in the air. It is going to become just as important as the elevator, and more important than the ailerons. Yep, you have to learn to fly both sticks, all of the time. That is why you built the little J-3.

It is an excellent trainer for our purposes, and is one bird that flies rather poorly if you don't do it properly. You will start to learn about taildraggers, and nice, gentle landings. Any other kind will get you in much trouble. In the little bird, a muffed landing will only bruise your ego, assuming you did all that beefing up we talked about earlier. In the biggies, with 15–30 pounds, you will bend something major if you blow a landing. Even something as minor as a nose-up becomes a catastrophe. Those big props cost a lot.

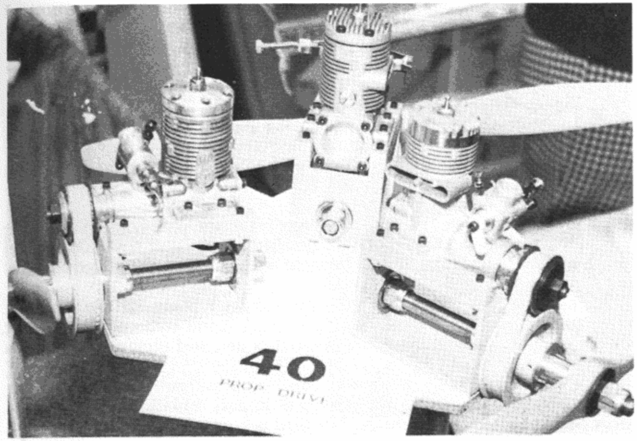
I'll tell you a little secret I have used for several years. If you will learn how to wheel-land that J-3, and will use that knowledge on the biggies, your landings will be much less of a sweaty proposition than if you use the standard full-stall touch-down. Reason? In the full-stall landing, control is lost at the moment of stall, hopefully at the exact same instant that the wheels hit the ground. If that timing doesn't happen, and it is rare that it does, you are left with a bird in a ticklish attitude, out of control, and with no airspeed. A really super pilot can sometimes recover from this situation. Mostly, the poor plane is on its own, to flop down any way it can.

If you will wheel-land the bird, the plane literally is flown down to the ground. Airspeed is maintained all the way through the touch-down, even through the initial part of the roll-out. Therefore, should things get out of whack at the last second, you still have some airspeed in the bank, and can use that speed to give you an extra edge to get out of trouble. I'm not saying that you now can get out of any situation. You still have to have a cool head, but at least you have a little something extra to work with.

The secret to a good wheel landing is a little extra airspeed. Carry that airspeed right down to the flare, and instead of trying to hold the plane off, concentrate on getting it into a level attitude just about an inch off the ground. In other words, instead of flaring, just break the glide at ground level. Now comes the scary part and the need for skill. With the



V-Power by Jenkins RC enables one to pair 40 or 60 engines onto one shaft. Comes in kit form and calls for exhaust mods. Ratios are 3:2 and just under 2:1.



D.C. Engineering make these units for 40 size engines to power 60 size models—a variation on the geared prop theme.

plane at one-inch altitude, and in a level attitude, tap in about a quarter-inch of down elevator, and hold it until the plane loses flying speed. If everything works out right, the plane will just gently tap its wheels down, and the down elevator will glue it onto the runway. As the speed drops off, come back easily to full-up elevator to avoid nosing over.

Practise this manoeuvre over and over with the Cub, and the skills developed will stand you in good stead for the rest of your flying career. Fail to do so, as most people do, and when you get serious with taildraggers, especially the biggies, you will spend more time repairing than flying. The full-stall landing is a killer. That's why in full-scale flying the perfect three-point landing is considered so beautiful. It is darned hard to do! The wheel landing is much safer, and the tail-high roll-out is the thing that turns on the crowds.

Having built the little one, learning all about the basic techniques of this type of model, you've mentally prepared yourself for the engineering and "beef" required in the powerful biggie. Your flying is so beautiful that every time you show up at the field your buddies put away their planes in shame, and you're hot to trot! What are you going to build?

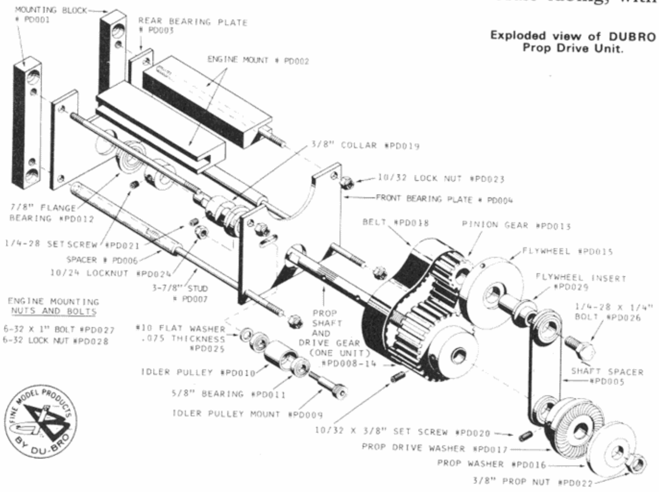
Here, I'm afraid that I have to turn you loose. So far, there just aren't many kits available, and only a few plans. In the U.S.A., there are sets of plans specifically designed for big engines. They are Andy Sheber's Pitts Special, and Kraft Super-Fli plans, available in both $\frac{1}{4}$ and $\frac{1}{3}$ scale, and Jim Folline's $\frac{1}{4}$-scale Quadra-designed PT-19. Also Sid Morgan's.

Then there are the Nosen kits, and I am flying a heavily-modified Nosen Champ. They are very good starting points for anyone. However, be advised that all of Bud's kits were designed to fly with a maximum of an ·80 engine and, consequently, they are very light in construction for the kind of power that is now the norm. They all fly very well, and are good, basic kits. They do require considerable beefing-up and redesign for the big engines.

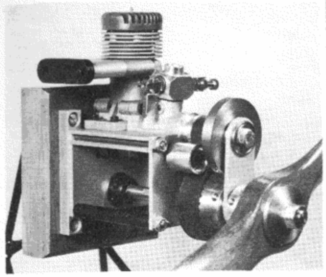
Since almost everyone starts with one of Bud's kits, I will go out on a limb to mention some of the things that we have all done in flying those models with the bigger power plants. First off, on all of the Nosen planes that have wing struts, the design is inadequate (for big engines), and is just about the single most important change you can make. These struts virtually take the full flight load. Redesign them with this in mind. Metal fittings on each strut end, bolted to strong metal attach points at both the wing and fuselage, is the only way to go. My struts have the metal cable shackle ends tied together with ⅛″ music wire running the length of the struts.

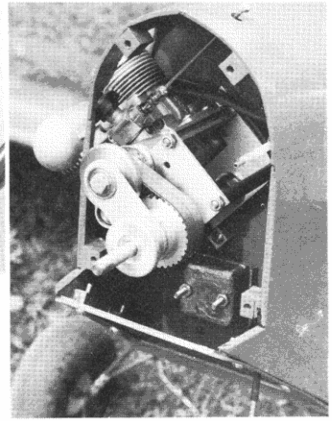
Second, you would be well advised to replace all the fuselage longerons with ¼″ hardwood dowel. The balsa wood structure just won't take the banging the heavier birds invariably get, and repairing them is a major project.

The nose area needs all you can do to stiffen it up. Look over carefully the wood supplied for this section, and replace any soft pieces with wood of a good hard density. My bird is covered inside and out with a layer of 8 oz. fibre glass, back to the rear of the landing gear on the outside. Since I cut out the door to make it operational, I stiffened the cabin area to replace the strength lost by this mod. The biggest things I did were to imbed ⅛″ wire into all the door and window posts, and to make forward pipe structure in the windshield from brass tubing, with wire splice pieces soldered into the joints, all ends tied heavily into the structure. The latter mod. alone greatly stiffened up the nose–cabin–wing area.



Exploded view of DUBRO Prop Drive Unit.





DU-BRO Prop Drive gives 5:2 ratio for 60 engines using a tensioned belt which gives approx six hours life. Right, installation in Nosen Gere Sport Biplane; O.S. 60 drives 22 10 in. prop to fly 24 lb. model, 8 ft. span.

The landing gear has to have some provision for flexing. As designed, it is almost totally rigid. Since the gear cannot flex, every hard landing will bend it when absorbing the shock. This is something that we haven't fully cured yet. There are several solutions that work, but are still not the ultimate. I have to leave this one to you: just to make some modification so that you do have some flex in the gear.

I don't like acetate windows. A trip to a plastics store will net you $\frac{1}{16}$″ Plexiglass. Careful cutting will get you some very nice windows that are even scale thickness! While you are there, pick up some very thick acetate or butyrate sheet (·040 or thereabouts) for the front windshield.

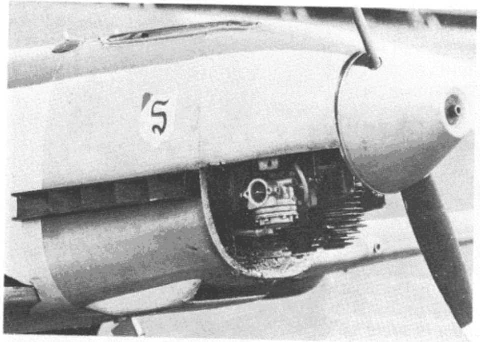
Now, as to engine choice, in general there are two types of engine available today. These are the glow engines that follow the standard modelling layout, and the converted industrial engines.

First, the glow engines that follow standard model design are not much different from the engines we have all grown to know and love, just bigger. From what I have seen of them, they are all very powerful, swing big props, and scream! They are best suited for the more modern, faster planes. There is no reason why they can't be used in the older bigger planes, but they don't match the character of those subjects.

The very light biggies, such as the Nosen J-3 and *Champ*, will be most satisfactory with glow engines, such as the Webra ·90 or one of the reduction drive units, of which there are several.

The bigger glow engines are usable in the lighter biggies, but are most at home in something like a Nosen *Citabria*, or ¼-*Pitts*.

Secondly, we come to the *pièce de résistance*, the Quadra class. The big, hulking monster prop-swingers. The Quadra can be used in virtually



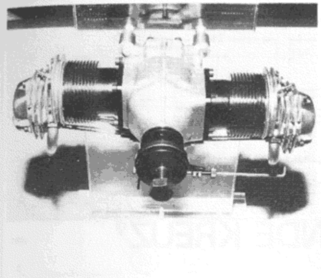
110 cc twin cylinder Stihl in Jim Davis' Me 109 is an ideal power unit for large, heavy models used in air-shows where it has been expertly operated by Dave Wright.

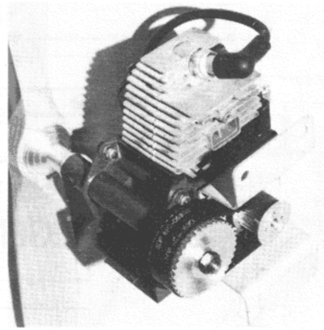
any big plane, but is most at home in one that matches its own bulk, such as the Nosen, *Mr. Mulligan*, or a $\frac{1}{4}$-*Pitts*. One of the most impressive sights I have seen was Jim Jacobson's 23-lb. *Mr. Mulligan* taking off on its maiden flight with the big Quadra growling away up front. That aeroplane rolled about 75 feet, pointed its snout up at about a 30° angle, and just clawed its way, growling, into the sky. There wasn't any real speed, just an awesome feeling of power. The closest comparison I can make was a 3000 h.p. Bearcat snarling away from the Reno runway. That is the kind of bird the Quadra was born for. It sounds so good!

I have a Quadra in my *Champ*, and it flies the plane very well. However, the engine completely fills the firewall, and the cowling is slightly oversize for scale. There are engines that would be a better match.

The *Quarter-Scale Association* was formed at the first Las Vegas National Fly-In, October '77. We are devoted to the building and flying of Quarter-Scale, or very large models. We believe that each and every huge model that is built is unique and special unto itself, and that there-

Quadra power in this Sherber half size(!) Pitts as flown at Woodvale during the 1978 World Champs. Weighs 27 lbs and flies well on an 18×6 in. Zinger prop. Builder is Bob Davis (left).





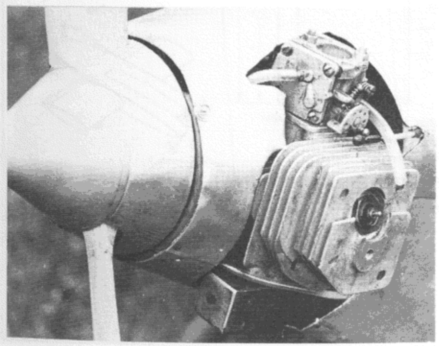
The O.S. "Big twin" four stroke is 20 cc as seen above at Nurnberg. Right, is Andy Sheber's Super-Drive for the Quadra has 2:1 ratio, turns a 24×10 in. prop up to 4,600 r.p.m., producing 22 lb. of thrust.

fore competition between them would be a sacrilege. Competition automatically implies rules and rules are restrictive. Basically, we are a bunch of individualists who wish to build what we want, how we want, and to get together with others to share the joy of achievements. We don't want those efforts formally judged, because every one of us is a winner in our minds.

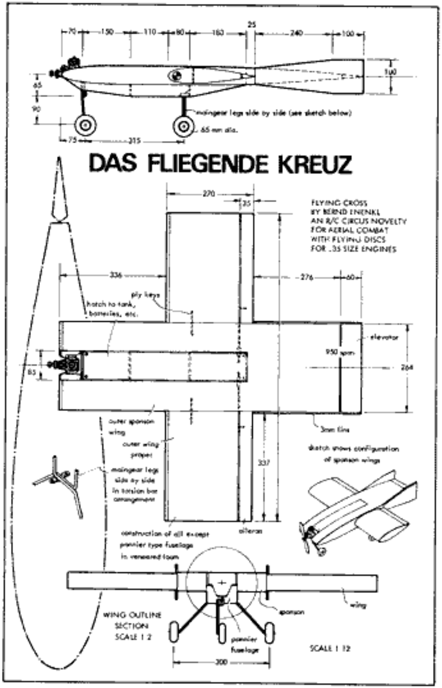
Our primary purpose is to provide a rallying point where anyone interested can get information, and share that which he has. We want to get together for fly-ins, Q.S. picnics, and barbecues, have a blast with our biggies, and enjoy the company of other guys like us. A newsletter is being published that is rapidly growing into a mini-magazine. It concentrates on the type of information that is so darned hard to come by.

If you are interested in the Q.S.A.A., send me a double-stamped, large self-addressed envelope, and I'll send you a copy of the first newsletter. (Lee Taylor, 329 C St., Roseville, CA 95678.)

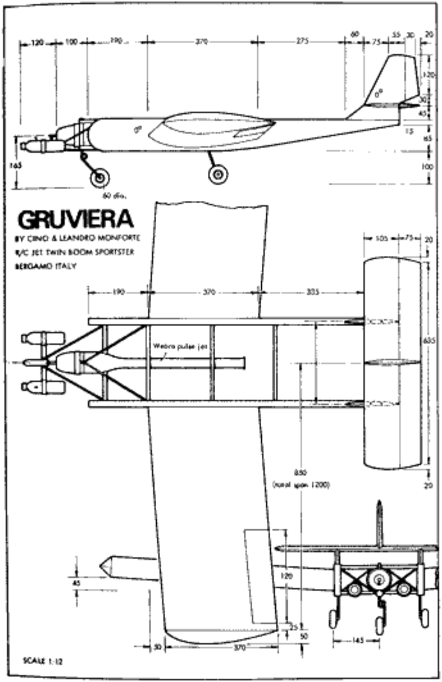
Remember. Big is Beautiful! (The Q.S.A.A. motto.)



Glowplug conversion using the standard $\frac{1}{4}$ in. plug in a big blank, makes the 56 cc Rowena a very useful two stroke—popular with the Jim Davis team. Also with Tony Cummins of Chester, who built this big scale Isaacs' Fury.



MODELBAUHEUTE GERMANY



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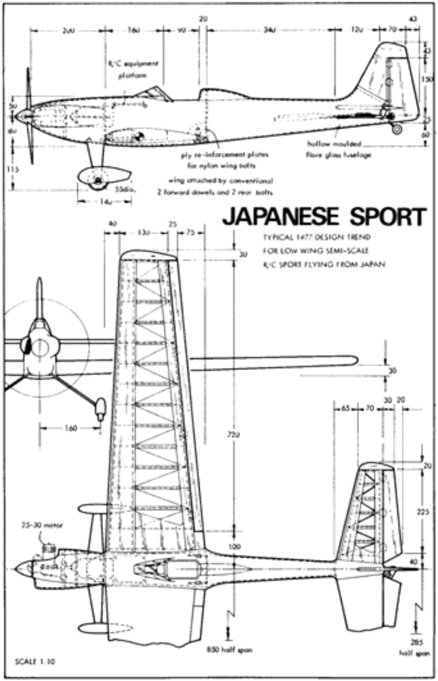
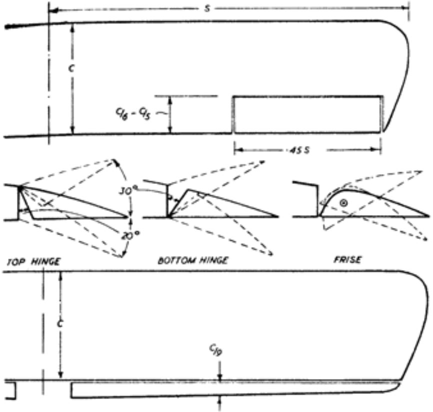


R/C TECHNIQUE JAPAN



DIFFERENTIAL MAKES A DIFFERENCE!

by Claude McCullough

(in "Radio Control Modeler")

SOME R/C fliers assume that ailerons should always be hooked up with equal up and down movement on either side of neutral. This is the easiest way and most standard pattern designs seem happy with equal aileron movement. In fact, some pattern designers are opposed to differential (as unequal movement is called). On models with fairly light wing loading, laid out to the requirements of a cut and tried formula emphasising symmetry between upright and inverted flight, tinkering would be daring and might be unprofitable. But this doesn't prove a case can't be made for aileron differential, particularly on scale models.

Let's take a look at *why*. As one aileron goes down and the other goes up, lift is increased on the first wing and decreased on the second, causing the aircraft to roll in the direction of the raised aileron. Simple, except the problem here is that the down aileron also creates a certain amount of drag at the same time which pulls the nose of the aircraft toward the down aileron side—just the opposite of the desired turn. At best, in some R/C models, this spoils the looks of manoeuvres (unless opposite rudder is fed in) and at worst can louse-up controllability completely.

The cure for this disease is to introduce a correction such as changing the movement of the ailerons so that the one going down moves less than the one going up, creating less drag in the process. You may be flying with a differential in movement already and not realise it. *Fig. 1* shows a common type of aileron construction used on many scale models as a building convenience. (In at least one full size prototype, this is the exact scale cross-section, the only difference being that the hinge has an even more practical location on the top surface of the wing, instead of below the planking. The designer of the *Shinn 2150*, now back in production in Phoenix must have been a modeller!) The rearward location of the horn behind the hinge point in *Fig. 1* gives less down movement and more up. The farther back the horn is placed, the greater the difference between down and up. This principle can also be applied to other aileron cross-sections.

William Bros. make 60 and 120° nylon bellcranks which produce differential movement. *Fig. 2* shows hook-up of the bellcranks to the ailerons. Note that the amount of movement can be increased or decreased by moving to appropriate pick-up holes, as is shown here for the aileron pushrod. The servo pushrod can also be shifted. Moving to other holes does not affect the differential, which is set by the angle of the horn.

Back in the early days of pattern flying, another way to eliminate the effects of adverse yaw was often used. Ed Kazmirski put Frise ailerons on his pioneer *Orion* and others followed the example. He said at the time that the aileron hinging of the *Piper Apache* inspired him to try the idea. *Fig. 3* shows the Frise aileron configuration. Any time you pick a scale subject having Frise type ailerons, be sure and use them. They will get extra scale points during judging as well as improve flying-performance. As for Ed. he dropped Frise ailerons from his next design, the classic *Taurus*, and opted—as everyone soon did—for the simplicity of strip ailerons that Harold deBolt had popularised. Differential can be easily introduced into strip ailerons by bending the wire horns away from the servo if the horns are below the wing (as on high-wing model) or toward the servo if they are above the wing (as on a low-wing model).

Bob Karlsson, U.S. Scale Contest Board representative from A.M.A. District IV and a long time scale and pattern flyer, believes in differential. Bob told me in a letter, "Differential aileron deflection is very often required in scale models. I've flown a model Smith *Mini-Plane* that at half speed turned the wrong way, due to the high drag of the down aileron! Our Curtiss Wright Jrs. required almost no down aileron at all. Most parasols behave this way, especially if they have dihedral. The more dihedral, the more differential required. We had a guy who put ailerons on an old deBolt Champ. It would not turn at all with ailerons. When all dihedral was removed, it responded fairly well. Differential made it almost normal."

Karlsson feels that the required amount of differential is hard to determine in advance, so he has worked up the system shown in *Fig. 4*, using a rotary servo wheel. For equal up and down movement, the aileron pushrods would be hooked into the centre hole. The further to either side of the centre hole the pick-up points are moved, the wider the differential between up and down movement. It can be carried to the point that no down movement of the aileron at all takes place.

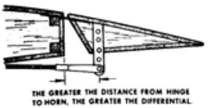


FIGURE 1

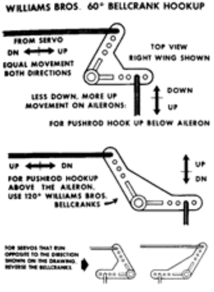


FIGURE 2

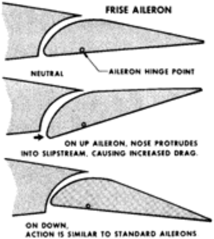


FIGURE 3

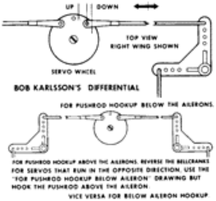
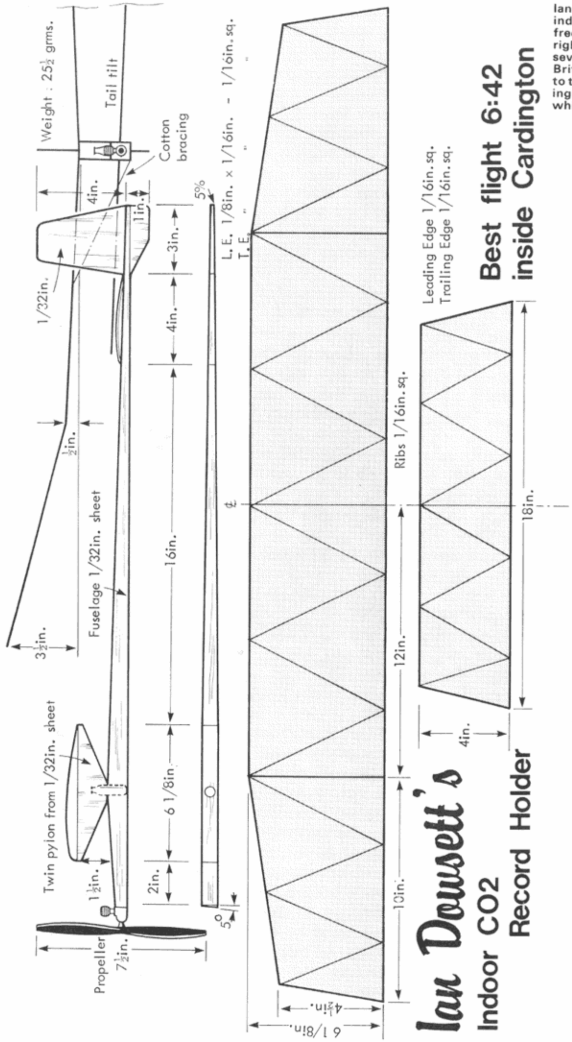
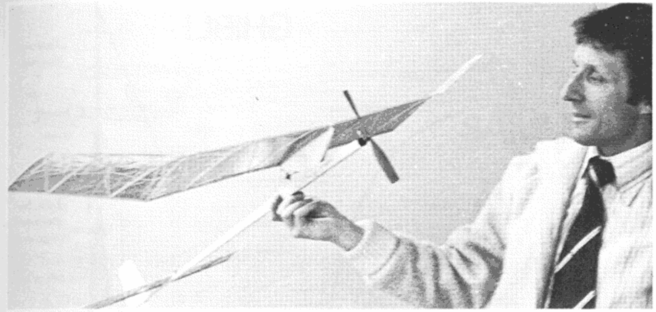


FIGURE 4

I've always incorporated differential aileron movement in my scale designs because full size practice and theory said it was the way to go. Even though some were fairly heavy, they flew and manoeuvred in a docile and no-vices manner. Given my below average piloting co-ordination, that is the type of flying I'm interested in. When checked out by better flyers, aerobatics did not seem to be adversely affected. So a question suggests itself: "Is equal movement of ailerons really the best for the specialised requirements of pattern aerobatics or is this just a common consensus opinion that has not been tested recently?" I know there are some dedicated pattern flyers who put in many long hours of practice trying different model set-ups. It would be interesting to hear from any who can comment on observations of performance with and without differential. When it comes to models, regardless of what a theory book says, there is no substitute for some practical, rule of thumb trials of what works and what doesn't work.



Ian Dowsett and his indoor mini pylon free flighter at right has inspired several other British modellers to try this challenging new trend which has great possibilities.

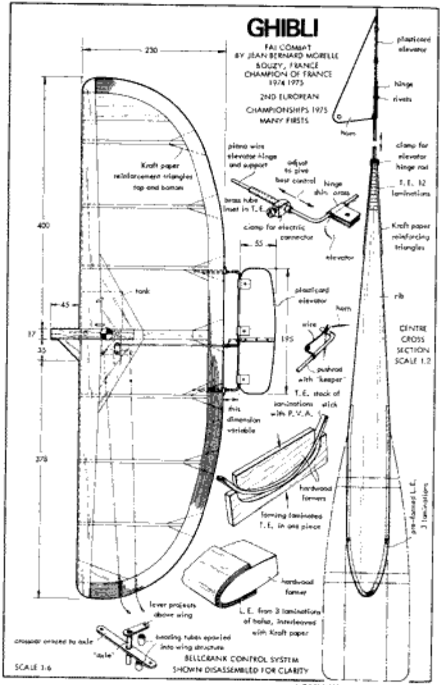


INDOOR CO_2 MODELS

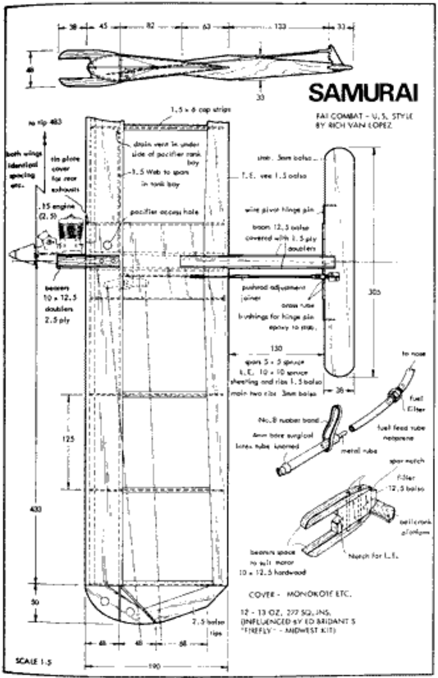
by Ian Dowsett

MY INTEREST in CO_2 powered models has now extended over many years and with the advent of the new generation of CO_2 motors, I happened to be in the right place at the right time to be asked to test several of these new engines. These small lightweight models appeal to me, even more so when one realises how quiet and efficient they can be. Outdoors, flights of 2–3 minutes are quite common but when I first saw them being used indoors in the airship hangar at Cardington I was so impressed I knew I would have to build one. Talking to two of the regular indoor flyers, Ron Green and Geoff Lefever, gave me plenty of ideas which quickly took shape to become the model you see here. It follows some of the American ½A designs having a large wing area and is built as light as reasonable structural strength permits. The all-up weight with the Telco motor is 26 g. The first six flights gradually increased from 4 min. 16 sec. to 5 min. 39 sec., then came that glorious flight of 6 min. 42 sec.—a new record! Motor run on this flight was 4 min. 40 sec. The model cruised around for 2 minutes at under 20 ft. and only after that, began to climb away.

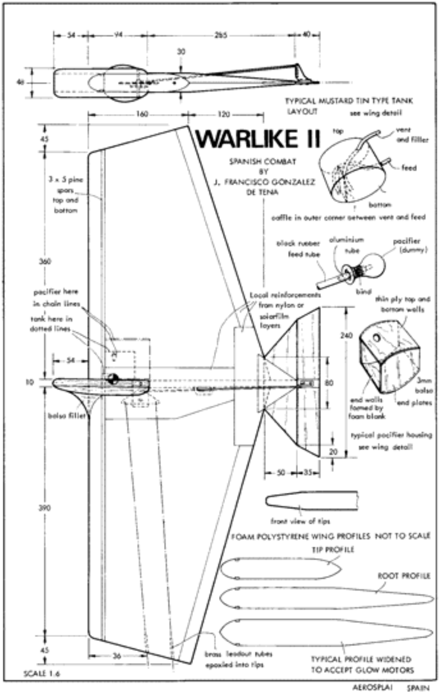
Covering is 4 thou. Mylar and the wing is cotton braced. The prop is probably the most important part of the model. The times first achieved were with a 7-in.-diameter prop but one of 9-in. diameter has also been tested. It is most important to use the initial low power of these CO_2 motors effectively, taking, say, 3 minutes to climb the first 25 ft. then using the faster climb to reach ceiling height—then hopefully a superb glide. This model could be capable of 10 minutes on a good day but like all of us my mind is already churning with ideas for the next design. This will have some features of the Gossamer Condor—wing surfaces covered top and bottom and probably around 48-inch span, weight 22–24 g. and, of course, a big prop. Dare we hope for 15-minute flights? *I do!*



MODELE REDUIT D'AVION FRANCE



MODEL BUILDER U.S.A.



1st FAG KALTENKIRCHEN "FLYING WING" CONTEST

Werner Thies (*Kaltenkirchen*)
Translated by **Hans Justus Meier**

IN SEPTEMBER 1977 the *Flugtechnische Arbeitsgemeinschaft* of *Kaltenkirchen* (FAG Kaltenkirchen) conducted a noteworthy contest for radio-controlled "flying wing" sailplane models; noteworthy because of the type of model flown and the novel competition rules used.

The models were flown in a stiff easterly breeze along a 30 ft. dune and had to cover a 100-metre course ten times. This new type of contest, initiated by Werner Thies, requires a model capable of flying at high speed and under precise control; only models possessing high manoeuvrability stand a chance to win a top place. In order to avoid ultra specialisation of model design a second criterion was introduced in the form of an altitude flight, with height measured across the top of the ridge, using a theodolite.

As the readers may remember, Werner Thies has made it a habit to evaluate contest results from a statistical point of view. The picture he derived from the figures and data is certainly interesting.

The Models

The absence of out-of-the-rut types, so often encountered in earlier years, was evident; in fact, few of the models belonged to the experimental class of flying wings, both as regards design and dimensions, the majority of them featuring the rather "classical" wing span of about 2500 mm.

While the builders of flying wing models generally aim at very low wing loadings now (having been severely handicapped in earlier years by unfavourable competition rules which required bringing free-flying wings up to the minimum wing loading specified for standard type models, although the "wings" could have been built much lighter) the models entered for the FAG Kaltenkirchen contest featured wing loadings in the 25 g./dm.^{2} region. Jürgen Landscron's model—which in the altitude test reached a height of 28·5 metres, not at all bad—had a still higher wing loading with 34·3 g./dm.^{2}.

Under the prevailing conditions, the stiff breeze reaching a velocity of 12–15 m./sec., the decision to enter models with heavier loading proved to be a wise one. These models seem to have been much lesser handicapped than a light loaded model would certainly have been.

The writer has been unable to discover a definitive trend re wing geometry; it seems a bit too early to try to come to any conclusion in this respect.

Moderate sweep angles ranging from 10° to 15° were used, with several competitors using no sweep at all. Of the latter some in reality featured slight negative sweep of the quarter chord line—the aerodynamically correct way of defining sweep angle. The model flown by J. Landscron proved an exception again in this respect—featuring a forward sweep of 8°.

While the "flying plank" type of model as a rule does not suffer from wing flutter, the swept wing now and then does when flown in the high-speed regime. It seems that flutter occurs mainly with models equipped with ailevators, that is a combination of aileron and elevator, when these control surfaces are not properly balanced statically.

With the exception of Dieter Paff, all contestants used Eppler airfoil section E-174–182 and 184, respectively, with very good results. Wings using the E-174–182 sections proved to be adequately stable only if used in conjunction with at least four degrees of washout. Models lacking built-in washout of this order had to set their ailevators at slight negative angles.

All models entered featured a centrally arranged vertical tail. Very little experimental data is available concerning the proper size of the short-coupled vertical tail surfaces. The product of fin moment arm and size is called vertical tail volume. A vertical tail (or directional) stability factor can be obtained by introducing wing area and semi-span values into a formula which reads

$$\frac{F.b/2}{rS.F/S}$$

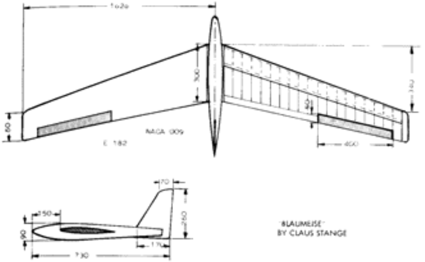
(with F = wing area, $b/2$ = semi span, rS = moment arm, F/S = fin area).

For the average R/C sailplane model of conventional configuration the directional stability factor should preferably be about 40 (large value = small fin area and small moment arm, respectively) although values ranging between 20 and 50 will be encountered.

With comparative data on tailless sailplane models being too scarce, it is difficult to select an optimum value for the flying wing type of model. With wing sweep angles and lateral area in front of the centre of gravity being factors which must be considered, it is necessary to collect more statistical material on this matter. In any case, the largest possible figure should be aimed at. Fins, too, produce drag and drag is something which must be reduced to a minimum in the quest for performance.

The stability factor of Dietrich Altenkirch's model with its moderate sweep was 71, that of Claus Stange's was about 67, while that of the swept model of Helmut Lange, who claims excellent control characteristics for this model, was 95.

Hans Jürgen Wolter, a DC-10 pilot by profession and for years an ardent model flyer, had the following to say about his model, which sports a wing span of 2240 mm. with a root chord of 420 mm., the moderately swept wing tapering to 230 mm. at the tip, resulting in a wing area of 72·8 dm.². "During early flight tests it became evident that longitudinal stability could not be obtained with the centre of gravity positioned at the calculated station—17 mm. aft of the leading edge at the mean chord station. The trailing edge ailerons with their 16% of wing chord depth and linear throw characteristics induced strong yawing oscillations which made a controlled circling flight nearly impossible. Ailerons using differential throw improved the situation somewhat, but it took an enlargement of the vertical tail surfaces to obtain positive control in turns." Initial



'BLAUMEISE'
BY CLAUS STANGE

size of the vertical tail surfaces had been 3·4 dm.² (for a stability factor of approx. 240). After an enlargement to 5 dm.², obtained by increasing the chord, the stability factor became 110, approaching that of the swept wing of Helmut Noffz and, incidentally, thus confirming our assumptions.

The majority of the models had no rudder, rather a fin only, with directional control achieved via operation of the ailerons. General pilot consensus was that directional control of their model by aileron was very good.

It is a well-known fact that aspect ratio is the only means for keeping induced drag low. A high aspect ratio means low induced drag, particularly at high lift coefficients (ca); at the lower ones aspect ratio is of lesser importance. When flying a model of small span a high aspect ratio results in a narrow wing chord and thus in a low Reynolds number, which is, of course, undesirable.

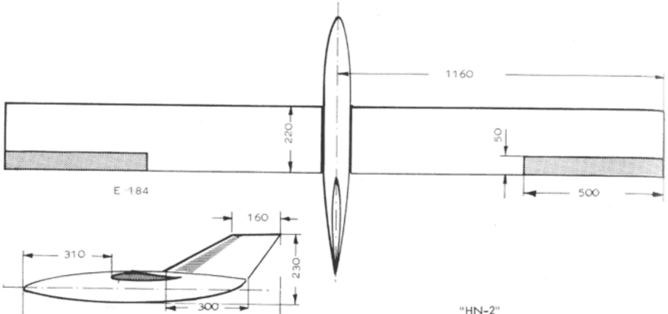
The 4-metre span model of Dieter Paff had the highest aspect ratio of all models entered (18·2), his smaller 3-metre model an aspect ratio of 13·9. The average figure for the other models was about 10, with the winning models of J. Landscron and D. Altenkirch sporting aspect ratios of 8·5 and 9·1, respectively.

The flying wings—in particular the swept ones—were generally controlled by ailevators, that is a control surface combining the functions of aileron and elevator. These systems are mechanically quite simple, but they suffer from becoming sensitive in the high-speed regime and from their tendency to flutter.

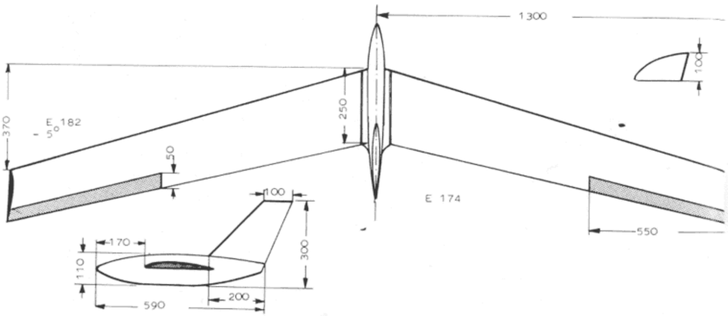
About 50% of the models, in particular those of the "flying plank" type, used separate control surfaces for yaw and pitch control (ailerons plus elevators).

As a rule the chord of the control surfaces was about 20–25% of the wing chord measured at the ailevator root station, their span about 30–40% of the semi-span of the wing. Differential control was generally used in the case of the ailerons, with up throw larger than down throw.

In their constructional methods the flying wing models did not differ noticeably from those of conventional-type contest models.

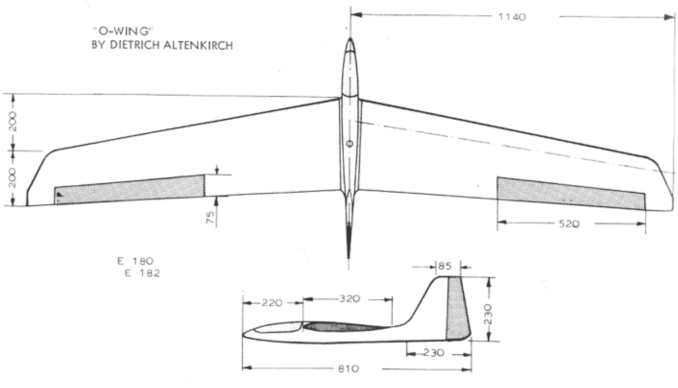


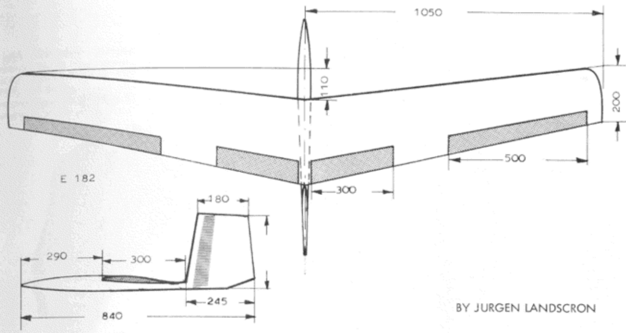
"HN-2"
BY HELMUT NOFFZ



"DWARS-LOPER"
BY GERHARD GATKE

"O-WING"
BY DIETRICH ALTENKIRCH





BY JURGEN LANDSCRON

Using the statistical data collected on this occasion for a basis we have come to the conclusion that the centre of gravity should preferably be positioned in the 20–22% of mean aerodynamic chord region. The mean aerodynamic chord is here defined as the one found at that station where a wing is bisected into two parts having the same area; it is thus not identical with mean chord.

In the case of swept flying wings of rectangular plan-form, such as the ones flown by Helmut Noffz, Walter and Ralph Becker, the centre of gravity position was still farther aft, namely at 25% of the chord at 40% of the semi-span station.

Dieter Paff's elegant 4 metre design has 1360 sq. in. area, is over 6 lb.

FAG CONTEST RESULTS

Speed contest (flight time in sec. per 1000 metres)

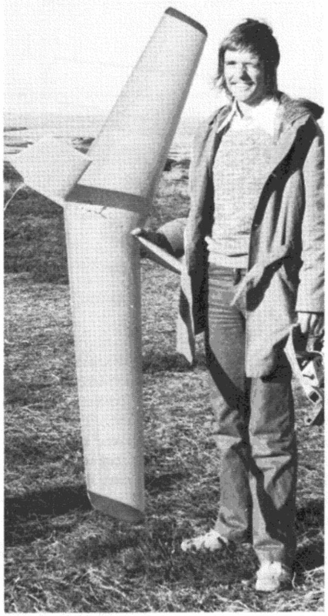
1. D. Altenkirch	71.1	0	65.3
2. J. Landscron	71.8	71.3	66.1
3. R. Sommer	90.9	96.0	95.6
4. H. Noffz	99.2	92.6	95
5. H. J. Wolter	128.6	98.5	92

Altitude contest (height in metres, measured across edge of cliff)

1. J. Landscron	22.9	28.5	27.6
2. D. Altenkirch	36.6	0	25.8
3. R. Sommer	31.1	19.4	17.7
4. H. J. Wolter	19.4	17.3	17.6
5. C. Stange	15.9	14.3	9.9

Total points (two speed and altitude runs)

1. J. Landscron	3990
2. D. Altenkirch	3935
3. R. Sommer	3067
4. H. J. Wolter	2695
5. H. Noffz	2428



Far left. Winner Jurgen Landscron with his swept-forward entry. Eppler 182 aerofoil, 1·85 kg. weight and separated ailerons and elevators, data at right.

Left. Second place went to Dietrich Altenkirch and the "O.Wing" which weighs 1·4 kg., changes aerofoil from E180 at root to E182 at tip, and has ailevators.

Left. Roland Sommer was third with his Vampir, weight 1·4 kg., has Roland's own aerofoil and employs separated elevator and ailerons.

TECHNICAL DATA OF SELECTED MODELS

Designer, name of model	Type of control	Aspect ratio	Wing loading	Weight	C.G. in % of mean Chord	Washout	Airfoil	Dihedral	Sweep	Wing area	Mean chord	Wing span
Dieter Paff PN 9	Elev. plus ailerons	13·9	35	2·3	21	-2	Own	3	-3	65	2·16	30
Dieter Paff	Rudder, elev.+ailer.	18·2	32	2·8	22	—	Own	3	-3	88	2·2	40
K. Niemeyer "Pilot 3"	Elev. plus ailerons			1·1		—	182	1	0			24·5
Roland Sommer "Vampir"	Elev. plus ailerons	12·4	27	1·6	26	-1·5	Own	—	0	60	2·3	26
Claus Stange "Blaumeise"	Ailevators	10	27	1·2		-4	009–182	1	15	44	2·1	21
Gerhard Gätke "Dwars-Löper"	Ailevators	12	32	1·8		-5	174 182	6	15			
H. J. Wolter	Linked airbrakes, ailevators	8·4	23	1·7		0	184	2	13	74·7	3·3	22·6
Jürgen Landscron	Elev. plus ailerons	8·5	34	1·8	22	0	182	3	-8	52·5	2·5	21
Dietrich Altenkirch "O-Wing"	Ailevators	9·1	25	1·4	20	-3	180 182	6		57	2·5	22·8
Schilling "Saracen"	Elev. plus ailerons	7	30	1·4		—		—		47	2·6	18
Carl Schefe	Ailevators	6·6	19	1·3		—	symm.	—		67	3·9	17
Walter Becher Entw. H. Noffz	Ailevators	9·7	22	0·92	25	-3	174 182	3	16	41	2·05	20
Helmut Noffz "HN 2"	Ailevators	10·7	30	1·5	20	0	E184	3	0	50	2·15	23·2
Helmut Noffz "HN 1"	Ailevators	11	22	0·9	25	-4	174 182	3	15	39·9	1·9	21

The Fun Event

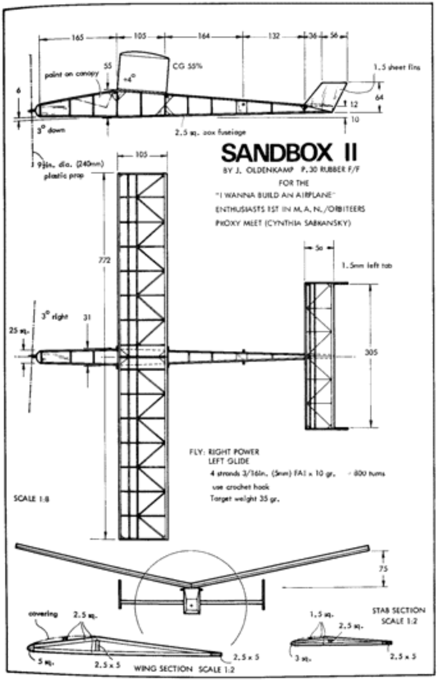
P-30

Orbiteers
SAN DIEGO

Originated by the San Diego Orbiteers as a fun event for novices to be flown at the U.S. Nationals and also used for a postal proxy contest with attendant publicity in *Model Airplane News*. The success of this new class was immediate. Forty-five entries in the first postal event endorsed the success of the formula and it is not difficult to see why. Specifications are extremely simple and the common denominators of a standard unmodified commercial plastic propeller on a 10 gram rubber motor ensure that everyone starts off on the same footing. Initially there was no special restriction on covering and the single surfaced "Derelict Dip P.30" ran away with the first event. Subsequent rule change introduced a standard form of top and bottom covered wing, but the relatively open specification for which only the span and length dimensions must not exceed 30 in. permit a wide variety of design approaches as can be seen in the following pages.

The Rules are:

1. No dimension of the airplane may exceed 30 in. (762 mm.) including the prop and the DT wires.
2. One unmodified 9½ in., commercial plastic free-wheeling propeller.
3. Ten (10) grams of rubber motor which must be enclosed in fuselage.
4. Tissue surfaces must be double covered.
5. Three minute max (40 second attempt).
6. Three flight total.



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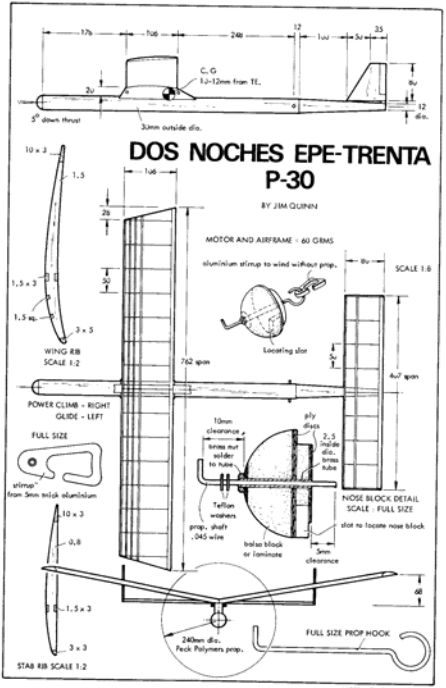

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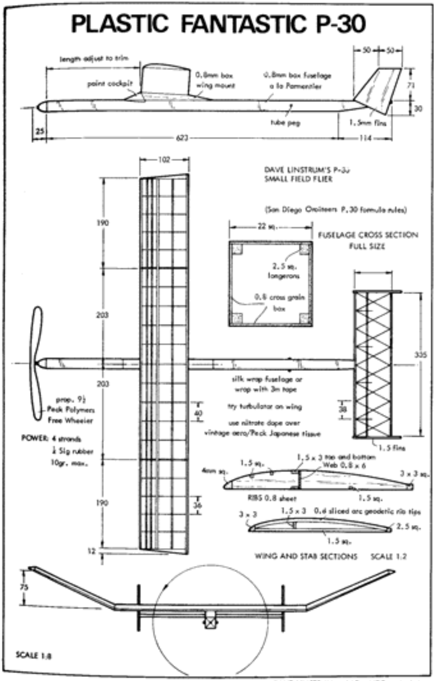
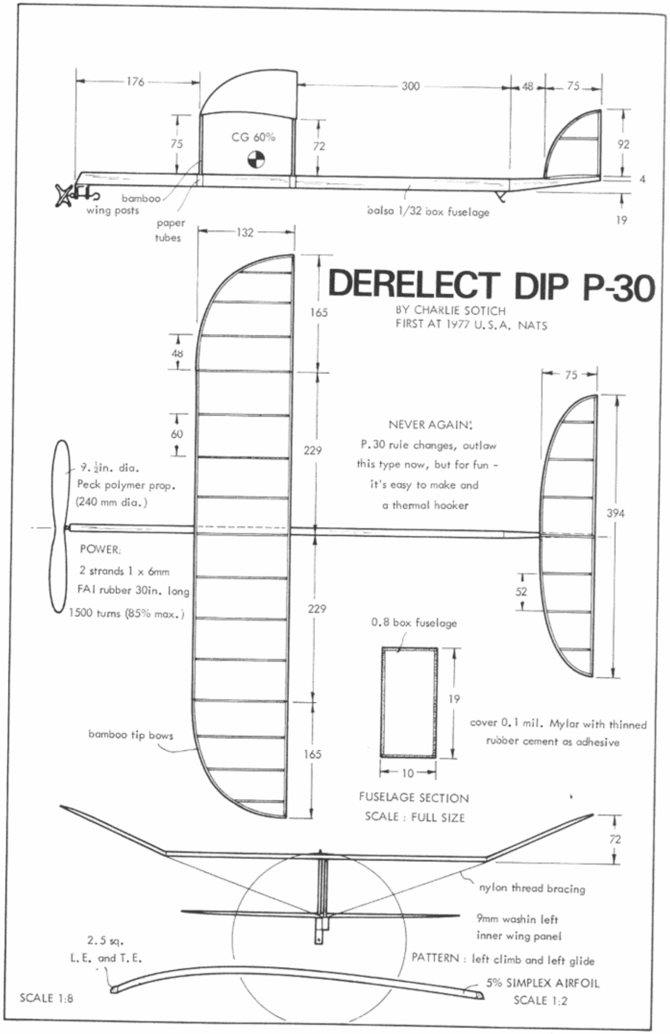


DAVE LINSTRUM N/L - VTO U.S.A.



NFFS U.S.A.

Dr. Brennig James is a well known glider pilot and a boomerang expert. He obtained Britain's 11th Diamond C, with a flight to 27,000 ft in a thundercloud (wearing a pair of swimming trunks) and has made the first 500 kilometre triangular goal flight in the U.K. He first became interested in boomerangs when he read an article by Felix Hess, and sought to develop boomerang throwing as a serious sport. With this in mind he has founded the Society for the Promotion and Avoidance of Boomerangs.

THROWING, MAKING AND UNDERSTANDING BOOMERANGS

by Felix Hess
(From "Australian Gliding")

"OF ALL the advantages we have derived from our Australian settlements, none seems to have given more universal satisfaction than the introduction of some crooked pieces of wood shaped like a horseshoe, or the crescent moon; and called boomerang, waumerang, or kilee. Ever since their structure had been fully understood, carpenters appear to have ceased from all other work; the windows of toy shops exhibit little else; walking-sticks and umbrellas have gone out of fashion; and even in this rainy season no man carries anything but a boomerang; nor does this species of madness appear to be abating."

The quotation is taken from an article in the *Dublin University Magazine* of February 1838, called *The boomerang, and its vagaries*. The anonymous author was the first to give a basically correct explanation of the returning boomerang.

In the present article we won't deal with such matters as the origin of boomerangs or the use of boomerangs by the Australian Aborigines. Rather we'll consider the returning boomerang as a—remarkable—physical object.

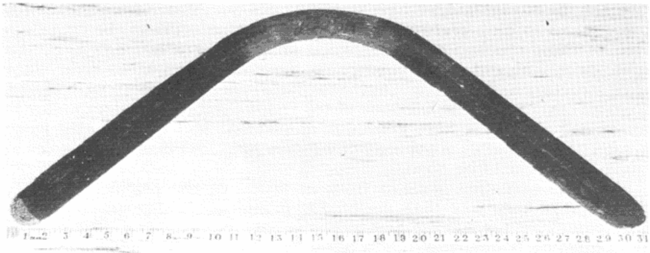
Usually a boomerang is thrown with its plane vertical (or slightly inclined with its upper part away from the thrower), in a horizontal (or slightly upward) direction, and with a considerable spin. At first the boomerang just seems to fly away, but it soon swerves to the left and also upwards, traverses a wide loop, approaches the thrower, and may descend somewhere near the thrower's feet, or describe a second, smaller, loop before reaching the ground. Generally, the boomerang's plane of rotation gradually "lies down", so that it may be nearly horizontal at the end of the flight. It is a splendid sight if a boomerang, quite near again after describing a loop, loses its forward speed, hovers some 5 metres above your head, and slowly descends like a helicopter or a maple seed. One should stand in the open air to see how very three-dimensional this phenomenon is and hear the soft, pulsating, swishing sound of the boomerang arms moving rapidly through the air.

A naïve observer might gain the impression that the boomerang is in the air for half a minute or so, whereas the real duration of the flight is typically about 8 seconds. Longer times are possible: the record duration of a boomerang flight witnessed by the author was 22 seconds.

A returning boomerang typically reaches a maximum distance of some 30 m. from the point of launching, and a maximum height of, say, 15 m. Lightweight boomerangs for indoor use may have flight paths with a diameter as small as 3 m. On the other hand, specially-designed boomerangs may reach much larger distances and still return completely.

Returning boomerangs may have various shapes, but they always consist of two or more arms lying approximately in one plane. An essential feature is the cross-section of the arms which is more convex on one side than on the other.

High aspect ratio boomerang by Dr. Brennig James using carbon fibre reinforcement in fibre glass.



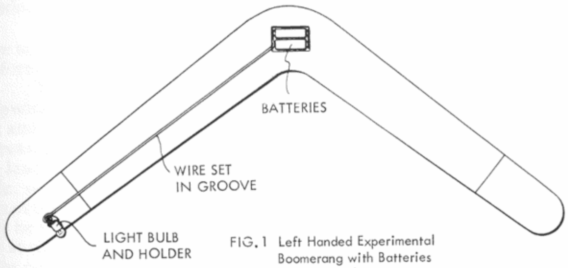


FIG. 1 Left Handed Experimental Boomerang with Batteries and light bulb

A boomerang is thrown by gripping it at one of its extremities, holding it up with the more convex side towards the thrower's cheek, and hurling it forward in such a way that the boomerang is released with a rapid spin. At the instant it leaves the hand its centre of mass moves much faster than the thrower's hand itself. In fact it is not at all difficult to launch a boomerang at a speed of 90 k/mh. To impart as much spin as possible to the boomerang, take care not to move the hand too fast, try even to stop the hand just before the instant of release.

The angle between the boomerang's plane of rotation at launch and the horizon (see *Fig. 2*) has a profound influence on the flight path. Most boomerangs should be launched at angles between 45° and 90°. If an ordinary boomerang is thrown at $\alpha = 0°–30°$, it soars up high in the air, and comes down either fluttering or at a terrific speed.

Usually a boomerang is suited to be thrown either with the right hand or with the left hand. Most boomerangs are right handed: their sense of rotation in flight is counterclockwise as viewed from the more convex side. If such a boomerang is made to rotate in the opposite direction, it generally does not behave like a good boomerang. The mirror-image of a right-handed boomerang, however, should rotate clockwise in order to work well. Such a left-handed boomerang is suited to left-handed throwers. In every respect a left-handed throw with a left-handed boomerang is the exact mirror-image of a right-handed throw. The flight path curves to the right instead of to the left, etc.

Optimum conditions for boomerang throwing are provided by a piece of grassland the size of a football field, without trees or nearby buildings. The weather should be almost windless, although some boomerangs perform best when the wind speed is about 3 m./s. If there is wind, the boomerang should be thrown to the right of windward (for right-handed boomerangs), so that the flight path is traversed almost completely upwind from the thrower. Always be very careful when people

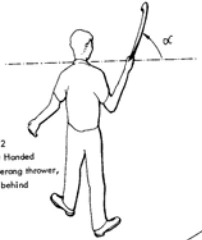
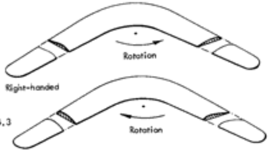


FIG. 2
Right Handed
Boomerang thrower,
from behind



(a) Right-handed

FIG. 3

(b) Left-handed Dots indicate centres of mass

are watching within close distance: boomerangs are capable of inflicting serious wounds.

The most important feature of a returning boomerang is the cross-section of its arms, which should be more or less like an airfoil section. The detailed shape of a boomerang's plan-form is less important. The angle included between the arms may vary between 70° and 130°, for boomerangs of the type sketched in *Figs. 3* and *4*. Quite different plan-forms are also possible. Returning boomerangs may for instance resemble the capital letters: C, H, L, S, T, U, V, X, Y, Z.

Making a good returning boomerang is not difficult. A suitable material is plywood of 0·5–0·8 cm. thickness. *Fig. 4* provides a fairly simple example. The dimensions, which are not critical, might be chosen as follows: plywood thickness: 0·7 cm., tip-to-tip length: 50 cm., angle enclosed between arms: 110°, width of arms 4·5 cm., somewhat more at the elbow. The amount of plywood required for one boomerang is 50 cm. × 20 cm. The boomerang weight will be about 130 g. Saw out the plan-form with a jig-saw. Bring upper side into desired shape with a rasp or file. The successive plies will be clearly visible and show whether the obtained shape is smooth and regular. Leave the underside flat. Round the leading edges and the tips, and sand the whole surface smooth. If the boomerang performs well in a couple of trial throws, paint it

all over with glossy lacquer. Bright colours are convenient when the boomerang occasionally does not return after flying into a tree. For a left-handed boomerang interchange A and B in *Fig. 4*.

The cross-section shown has a blunt leading edge, a sharp trailing edge and a smooth surface. This may not be necessary. Some boomerangs perform well with rough surfaces or pieces broken off.

The practice of making and throwing boomerangs suggests the following rules of thumb. If a boomerang "lies down" too much, soars up, and does not return, but describes only an open loop, it may help to increase the "lift" on one arm by filing away a bit of the underside near the leading edge. On the other hand, if the boomerang "lies down" too little, so that after describing half a loop it loses height too fast, file away a bit of the other arm in a similar manner. A boomerang's hovering qualities may be improved by filing away both arms near the trailing edges, especially at the tips. If one desires to increase the dimensions of a boomerang's flight path, ballast may be attached near both wing tips, preferably inside the boomerang, or on the flat underside.

The flight of boomerangs is a complicated phenomenon: on the one hand, the boomerang's motion depends on the forces exerted by the air, on the other hand, these forces depend on the boomerang's very motion. However, any explanation of the return behaviour of boomerangs must be based on these two principles:

1. the boomerang's arms are wings,
2. the boomerang spins rapidly and behaves as a top.

Let us first consider principle 1: *the boomerang's arms are wings.*

Just like an aeroplane wing, a boomerang arm experiences aerodynamic lift and drag. As we've seen, a right-handed returning boomerang is usually thrown in such a way that its plane of rotation is nearly vertical, the more convex side facing towards the left. As a result, the "lift", instead of pointing upwards as with an aeroplane, points towards the left; one might, therefore, expect the boomerang to swerve to the left as indeed it does. However, this is only one part of the explanation.

In the following, we shall refer to a cross boomerang, just for convenience. For differently-shaped boomerangs the explanation is the same. The length of the boomerang's arms (from boomerang's centre of mass to tips) is **a**. The boomerang has a forward speed **V**, and a rotational speed ω.

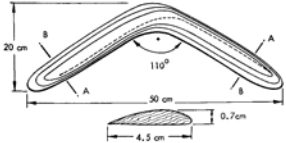


FIG. 4
Right-handed Boomerang A = L/E B = T/E (Reverse for Left Handers)

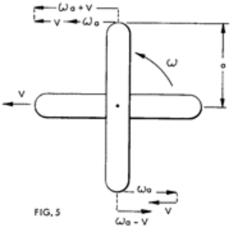


FIG. 5

At any instant, not all parts of the boomerang have the same velocity. This is due to the combination of the forward speed and the rotational speed. The upward-pointing end of the boomerang moves faster than the downward-pointing end, as is indicated in *Fig. 5*. Hence the uppermost parts of the boomerang experience much stronger leftward forces than the lower parts do. This means that the aerodynamic forces not only produce a net leftward force **F**, but also a net torque **T**, which tries to cant the boomerang with its upper part to the left: counterclockwise as seen from the thrower. See *Fig. 6*. This canting would be about an imaginary horizontal axis, called the torque axis. However, we do not observe such canting in boomerangs!

At this point we must consider principle 2: *the boomerang spins rapidly and behaves as a top.*

Put a top upon its peg, and it will, of course, topple over. But give it a fast spin, and it can stand upright. The difference is due to the rapid rotation. A spinning top reacts in a peculiar way to an applied torque: it does not give way to the torque, but rotates slowly about an imaginary axis perpendicular to both the spin axis and the torque axis. See *Fig. 7*.

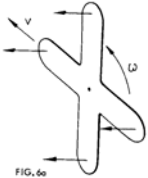


FIG. 6a

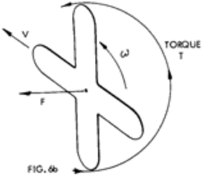


FIG. 6b

This motion is called precession. A boomerang behaves just the same way. Here the spin axis is horizontal, to the left, the axis of the aerodynamic torque **T** is visible, directed backwards towards the thrower, and the axis of precession moves with its foremost part to the left and rotates slowly with an angular precession velocity Ω counterclockwise as viewed from above. Thus the boomerang turns its foremost part, rather than its uppermost part, to the left. In daily life, this phenomenon of precession is exploited, when one bicycles "with no hands" through a curve: leaning to the left makes the spinning front wheel turn to the left.

From our explanations so far the following picture emerges. The boomerang originally moves horizontally forwards, its plane of rotation vertical. Soon it swerves to the left because of the net force **F**. At the same time it responds to the net torque **T** by slowly moving its foremost part to the left.

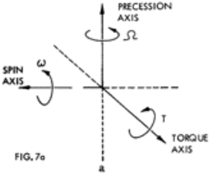


FIG. 7a

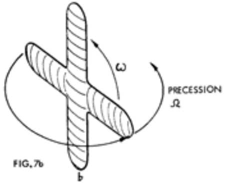


FIG. 7b

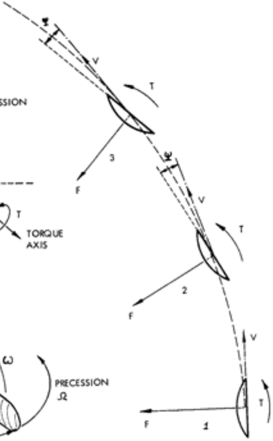


FIG. 8

Let Ψ be the angle between the boomerang's plane of rotation and the direction of its forward speed. If $\Psi = 0$, the boomerang moves parallel to its own plane. If $\Psi > 0$, the boomerang is inclined with respect to its forward motion, and the aerodynamic forces will be larger. This is because each section of the boomerang arms will have a larger angle of attack.

If the torque **T** causes Ψ to increase, **F** will increase also, pushing the boomerang to the left and keeping Ψ from increasing too much. The result is a curved flight path, traversed at a rather small angle of incidence Ψ. See *Fig. 8*.

The above explanation makes it understandable how a boomerang can traverse a more of less circular loop, and return to the thrower. During the flight a boomerang is pulled down by its weight, and it should of course complete its loop before dropping to the ground. If the boomerang moves with its plane not vertical, *i.e.* if $\alpha = 90°$, the force **F** may have an upward component, which counteracts the weight, and keeps the boomerang in the air longer.

What about the size of a boomerang's flight path? Let us consider a simple case. Suppose a boomerang flies approximately along a horizontal circle, with its plane of rotation vertical ($\alpha = 90°$), and with a small, constant angle of incidence Ψ. The boomerang's forward velocity be **V** (m./s.), it spins Ψ (rad./s.), 1 revolution $= 2\pi$ radians. For a rapidly-spinning object, the precessional velocity Ω (rads./s.) is related to the torque **T** and the spin Ψ according to the formula:

$$\Omega = \frac{\mathbf{T}}{\mathrm{I}\,\omega} \qquad (1)$$

Here I is the object's moment of inertia with respect to the spin axis.

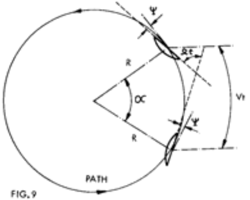


FIG. 9

Let **R** be the radius of the circular flight path (see *Fig. 9*). In **t** seconds the boomerang traverses an arc with a length of **Vt** metres. The angle, as seen from the path's centre, covered by this arc be α, so that the arc's length equals $\alpha\mathbf{R}$. Hence: $\mathbf{R} = \mathbf{Vt}$. In the same time interval the boomerang precesses over an angle $\Omega\mathbf{t}$. If the boomerang's angle of incidence Ψ (angle between boomerang's plane and flight path) is to be constant, we have the condition

$$\mathbf{t} = \Omega = \alpha. \quad \text{Hence} \quad \Omega\mathbf{tR} = \mathbf{Vt} \quad \text{and} \quad \Omega\mathbf{R} = \mathbf{V}. \qquad (2)$$

To make the boomerang fly along a curved path with radius **R**, a centripetal (directed towards circle's centre) force is required of magnitude $\mathbf{mV^2/R}$, where **m** is the boomerang's mass. This force, of course, is supplied by the aerodynamic force **F**. Therefore:

$\mathbf{mV^2}$

$$\mathbf{F} = \frac{\mathbf{mV^2}}{\mathbf{R}} \qquad (3)$$

For the flight path radius **R** we obtain:

$$\mathbf{R} = \frac{\mathbf{mV^2}}{\mathbf{F}} \qquad (4)$$

Also, from (1) and (2) follows:

$$\mathbf{R} = \frac{\mathbf{V}}{\Omega} = \frac{\mathrm{I}\,\omega\mathbf{V}}{\mathbf{T}} \qquad (5)$$

From (4) and (5) follows the condition:

$$\frac{\mathbf{T}}{\mathrm{I}\,\omega} = \frac{\mathbf{F}}{\mathbf{mV}} \qquad (6)$$

Both **T** and **F** depend on the angle of incidence Ψ. Therefore Ψ must have such a value that (6) is satisfied. Usually this is not the case, and the flight path is not a precise circle.

What happens if one launches the same boomerang at a higher speed, so that both **V** and Ψ are increased? Does the flight path become larger? Let us see.... According to (4) **R** seems to increase if **V** does. On the other hand, **F** also increases with **V**. If we assume that the ratio $\omega/\mathbf{V}$ is the same at each launching (which seems not unreasonable), and, moreover, that also Ψ remains the same, then **F** turns out to be proportional to $\mathbf{V^2}$ according to aerodynamic theory. Hence **R** remains unchanged, according to (4). This means that the flight path radius is independent of how fast one launches the boomerang! In a sense: *each boomerang has its own flight path radius.* This is indeed confirmed by experiments.

If a boomerang is made more massive (by making it from heavier material, or by attaching ballast), so that both **m** and I are increased, but its shape remains the same as before, (4) and (5) show that the flight path radius will be larger.

At this point, the reader may wonder whether straight-flying boomerangs are possible at all. They are. Suppose we launch a boomerang in a horizontal direction with its plane approximately horizontal ($\alpha = 0$), and that the net force **F**, which is a real lift in this case, just balances the boomerang's weight. Suppose further that the net torque **T** would vanish, then the precession would be absent, and the boomerang would keep its plane horizontal: it would fly straight on. How can we provide a boomerang with a positive net force **F** and a zero net torque **T**? Give

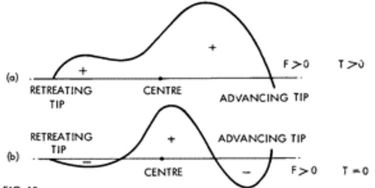


FIG. 10

the boomerang's wings a negative angle of attack at the tips, and a positive angle of attack near the boomerang's centre. One might call the result a negative twist. The lift distribution then would have a negative part near the tips, and a positive part in the middle, as indicated in *Fig. 10*.

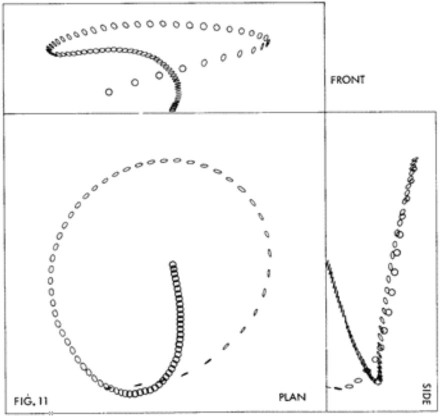


FIG. 11

The foregoing provides only a qualitative explanation of a boomerang's remarkable behaviour. It is possible to set up a detailed mathematical theory for the aerodynamics and motion of boomerangs, and to calculate boomerang flight paths on the basis of such a theory. A high-speed computer is indispensable here. As an example, *Fig. 11* shows a computer plot of a theoretical flight path. The boomerang is represented symbolically by a circular disc in perspective, and its position is shown at intervals of 0·1 sec.

Experimental research on boomerangs need not be as sophisticated. The flight path can be recorded by an ordinary camera. Time exposure traces a battery-fed light mounted in a boomerang. Since boomerang arms operate at low and Reynolds number (0–100,000), a region on which very little research has been done, it is difficult to give rules for "optimum" boomerang arm sections. Any dedicated hobbyist could make new contributions to this field by carefully shaping boomerangs and observing their flights.

Recent non-specialist articles on boomerang mechanics:
(1) Hess, F. "The aerodynamics of boomerangs." *Scientific American*, Vol. 219 No. 5, November 1968, pp. 124–136.
(2) Musgrove, P. J. "Many happy returns." *New Scientist*, Vol. 61 No. 882, 24 January 1974, pp. 186–189.

Available books on boomerangs:
(1) Mason, B. S. *Boomerangs, how to make and throw them.* (Dover Publ., New York, 1974) 99 pp. (reprint from 1937) (emphasis on six-armed boomerangs).
(2) Urban, W. *Geheimnisvoller Bumerang, Kleines Lehrbuch.* (Gerda Urban, 8801 Leutershausen, W. Germany, 1966) 58 pp. (excellent German textbook on boomerang-throwing technique).
(3) Ruhe, B. *The boomerang.* (Smithsonian Associates Workshops, Washington D.C., 1972) 30 pp. (Ruhe knows about every boomerang activity anywhere in the world).
(4) Hanson, M. J. *The boomerang book.* (Kestrel/Puffin books, Penguin, 1974) 48 pp. (pays attention to left handers). 95p.
(5) Hess, F. *Boomerangs, aerodynamics and motion.* (Author, Groningen, Netherlands, 1975) 555 pp. (comprehensive but mostly technical. Contains stereoviewer to view 3-D experimental and theoretical boomerang flight paths).
(6) Smith, H. A. *Boomerangs, making and throwing them.* (Gemstar Publ., Littlehampton, Sussex, 1975) 33 pp. (pays attention to long-distance boomerangs).
(7) Hawes, L. & M. *All about boomerangs.* (Hamlyn, Sydney, 1975) 72 pp. (Hawes is an Australian boomerang maker).

Boomerang Clubs
(1) "Boomerang Association of Australia", c/o Morris Maxwell, 45 Rose Street, McKinnon, Victoria 3204.
(2) S.P.A.B. (Society for the Promotion and Avoidance of Boomerangs), Major Chris Robinson, 12 Stoneham Close, Reading, Berks.

OFFICIAL MANHATTAN RULES

from "Star Skippers Newsletter"

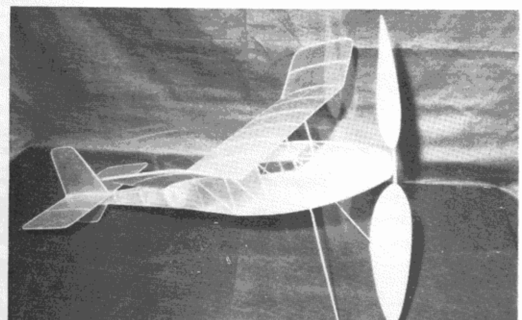
The OFFICIAL Manhattan Formula Rules

1) Airframe Weight, less rubber ... minimum 4 grams.
2) Overall Length ... 20 in. maximum measured from front of propeller bearing, aft.
3) Fuselage: (a) Must support and enclose a single rubber motor. No motor sticks permitted.
   (b) Must include a "box" $2\frac{1}{2}$ in. $\times$ 4 in. $\times$ 2 in. or larger.
   (c) Must have a windshield of 2 sq. in. minimum area, plus a window on each side of 1 sq. in. minimum area covered with cellophane or similar transparent material.
4) Prop ... All wood, direct drive, fixed pitch.
5) Wing ... Monoplane with maximum projected span of 20 in. and maximum 4 in. chord. Wood bracing allowed.
6) Stab ... Monostab with maximum projected span of 8 in. and maximum $3\frac{1}{2}$ in. chord. Wood bracing allowed.
7) Landing Gear ... Rigid and fixed with at least 2 wheels of 1 in. diameter. Must be able to support aeroplane.
8) Covering ... Except for windshield and windows, only paper (condenser paper included) is permitted. No film or microlite is allowed.
9) Flying ... All flights at least two point R.O.G. Best single flight counts of unlimited number of official flights (or of limited number of flights if desired).

These official rules reflect almost 100% the M.I.A.M.A. Rules, and the way they have matured in Manhattan. They work well, and have drawn a lot of interest. Modellers elsewhere may like the event better with their own slight variations. They are certainly entitled to their preferences. What Star Skippers of New York are doing is setting down, once and for all, what the OFFICIAL Rules are. In Indianapolis they fly the event with a 5 g. minimum. In England they require a 6 g. minimum and the wing must be mounted flush on the fuselage. Fly the event the way *you* like it; but with the OFFICIAL Rules established, you will know just what your variations are.

Opposite. John Triolo and his second place Manhattan formula model at the Columbia University Halls meeting in January 1978—Ed Whitten photo.

Left. A change for Henry Tubbs of Leeds is his first Manhattan seen in Cardington during 1978 summer meetings. Henry likes the formula.



Right. Pete Andrews won the Columbia University event, also at Cantague in April 1978 with his parasol-winged design. Not much forward vision for the pilot, Pete!

F.A.I. WORLD RECORDS
(as at 1–8–78)

Free Flight
Class F-1-B
RUBBER DRIVEN

No. 1 **Duration**
V. Fiodorov (*U.S.S.R.*), June 19th, 1964 .. .. 1h. 41m. 32s.
No. 2 **Distance in a straight line**
G. Tchiglitsev (*U.S.S.R.*), July 1st, 1962 .. .. 371·189 km.
No. 3 **Altitude**
V. Fiodorov (*U.S.S.R.*), June 19th, 1964 .. .. 1,732 m.
No. 4 **Speed in a straight line**
P. Motekaytis (*U.S.S.R.*), June 20th, 1971 .. .. 144·9 km/h.

POWER MODELS
Class F-1-C

No. 5 **Duration**
I. Koulakovsky (*U.S.S.R.*), August 6th, 1952 .. .. 6h. 1m.
No. 6 **Distance in a straight line**
E. Boricevitch (*U.S.S.R.*), August 15th, 1952 .. .. 378·756 km.
No. 7 **Altitude**
G. Lioubouchkine (*U.S.S.R.*), August 13th, 1947 .. .. 4,152 m.
No. 8 **Speed in a straight line**
Doubenitsky (*U.S.S.R.*), June 25th, 1973 .. .. 173·45 km/h.
No. 44 **Seaplane Duration**
R. Weber (*U.S.A.*), May 16th, 1978 .. .. 5m. 36s.
No. 45 **Seaplane Distance in a Straight Line**
M. Sulc (*Czechoslovakia*), October 3rd, 1973 .. .. 15,700 m.
No. 46 **Seaplane Altitude**
M. Sulc (*Czechoslovakia*), October 3rd, 1973 .. .. 1,960 m.

RUBBER-DRIVEN HELICOPTER
Class F-1-F

No. 9 **Duration**
A. Nazarov (*U.S.S.R.*), June 3rd, 1968 .. .. 33m. 26·7s.
No. 10 **Distance in a straight line**
Giulio Pelegi (*Italy*), August 3rd, 1974 .. .. 5,237 m.
No. 11 **Altitude**
P. Motekaitis (*U.S.S.R.*), August 30th, 1975 .. .. 812 m.
No. 12 **Speed in a straight line**
P. Motekaitis (*U.S.S.R.*), June 12th, 1970 .. .. 144·23 km/h.

POWER-DRIVEN HELICOPTER
Class F-1-A

No. 13 **Duration**
S. Purice (*Rumania*), October 1st, 1965 .. .. 3h. 12m.
No. 14 **Distance in a straight line**
V. I. Titlov (*Hungary*), October 1st, 1963 .. .. 91·491 km.
No. 15 **Altitude**
S. Purice (*Rumania*), September 24th, 1963 .. .. 3,750 m.
No. 16 **Speed in a straight line**
A. Pavlov (*U.S.S.R.*), September 20th, 1970 .. .. 116·12 km/h.

GLIDERS
Class F-1-A

No. 17 **Duration**
M. Milutinovic (*Yugoslavia*), May 15th, 1960 .. .. 4h. 58m. 10s.
No. 18 **Distance in a straight line**
Z. Taus (*Czechoslovakia*), March 31st, 1962 .. .. 310·33 km.
No. 19 **Altitude**
G. Benedek (*Hungary*), May 23rd, 1948 .. .. 2,364 m.

INDOOR MODELS
Class F-1-D

No. 32 **Duration**
Cat. 4. D. Kowalski (*U.S.A.*) August 4th, 1976 .. .. 50m. 41s.
No. 32a Cat 1 **Less than 8 m. ceiling Duration**
T. F. Vallee (*U.S.A.*), August 22nd, 1975 .. .. 22m. 45s.
No. 32b Cat 2 **8–15 m. celing Duration**
Jiri Kalina (*Czechoslovakia*), August 26th, 1970 .. .. 30m. 7s.
No. 32c Cat 3 **15–30 m. Ceiling Duration**
Bucky Servaites (*U.S.A.*), June 2nd, 1977 .. .. 35m. 08s.

RADIO CONTROL POWER DRIVEN
Class F-3-A

No. 20 **Duration**
R. Weber (*U.S.A.*), June 10th, 1978 .. .. 15h. 47m. 50s.
No. 21 **Distance in a straight line**
R. Weber (*U.S.A.*), August 16th, 1975 .. .. 428 km.
No. 22 **Altitude**
M. Hill (*U.S.A.*), September 6th, 1970 .. .. 8,208 m.
No. 23 **Speed in a straight line**
Goukoune and Myakinine (*U.S.S.R.*), September 21st, 1971 .. .. 343·92 km/h.
No. 31 **Distance in a closed circuit**
Richard Weber (*U.S.A.*), May 31st, 1976 .. .. 683 km.

R/C SEAPLANE

No. 48 **Duration**
R. Weber (*U.S.A.*), September 2nd, 1977 .. .. 9h. 7m. 37s.
No. 49 **Distance in a straight line**
R. Weber (*U.S.A.*) October 8th, 1977 .. .. 244·8 km.
No. 50 **Altitude**
M. Hill (*U.S.A.*), September 3rd, 1976 .. .. 5,651 m.
No. 51 **Speed in a straight line**
Goukoune and Myakinine (*U.S.S.R.*), October 25th, 1971 .. .. 294 km/h.
No. 52 **Distance in a closed circuit**
R. Weber (*U.S.A.*), September 2nd, 1977 .. .. 508 km.

R/C GLIDERS
Class F-3-B

No. 24 **Duration**
E. Miakinine (*U.S.S.R.*), September 30th–October 1st, 1973 .. .. 25h. 44m. 8s.
No. 25 **Distance in a straight line**
J. R. Hiner (*U.S.A.*), May 24th, 1975 .. .. 51·28 km.
No. 26 **Altitude**
Raymond Smith (*U.S.A.*), September 2nd, 1968 .. .. 1,521 m.
No. 33 **Speed in a straight line**
W. Sitar (*Austria*), June 18th, 1977 .. .. 390·92 km/h.
No. 34 **Distance in a closed circuit**
C. Aldoshin (*U.S.S.R.*), October 24th, 1974 .. .. 522 km.

R/C HELICOPTER
Class F-3-C

No. 35 **Duration**
H. Pallmann (*Germany*), July 13th, 1974 .. .. 1h. 45m.
No. 36 **Distance in a straight line**
N. Rambo (*U.S.A.*), January 26th, 1974 .. .. 2,509 m.
No. 37 **Altitude**
H. Pallmann (*Germany*), July 31st, 1974 .. .. 1058 m.
No. 38 **Speed in a straight line**
Hubert E. Bitner, Jr. (*U.S.A.*), October 17th, 1976 .. .. 56·484 km/h.
No. 39 **Distance in a closed circuit**
D. Schluter (*W. Germany*), June 20th, 1970 .. .. 11·5 km.

CONTROL LINE
Class F-2-A

No. 27 **Speed (2·5 c.c.)**
S. Jidkov (*U.S.S.R.*), September 22nd, 1975 .. .. 290·30 km/h.
No. 28 **Speed (2·5–5 c.c.)**
McDonald (*U.S.A.*), November 15th, 1964 .. .. 288·95 km/h.
No. 29 **Speed (5–10 c.c.)**
V. Kouznetsov (*U.S.S.R.*), September 30th, 1962 .. .. 316 km/h.

JET MODELS

No. 30 **Speed**
L. Lipinsky (*U.S.S.R.*), December 6th, 1971 .. .. 395·64 km/h.

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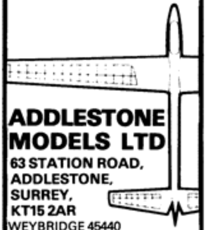

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