The Flightline

Volume 43, Issue 8 | Newsletter of the Propstoppers RC Club | AMA 1042 | August 2013

President's Message

Well the wet weather is not slowing down the flying. The fields are being well used. Thanks for all that come out and help to train. This may be the year that all of the members, including ME that get to burn up the skies once again. Thanks Jeff Frazier, Mike Williams and all that helped. Don't forget the last Picnic will be Sept 28th 3p.m. till dark; food will be cooked by A FAMOUS WORLD TRAVER DICK BARTKOWSKI.

Try and bring a show & tell to the meeting

Dick Seiwell, President

Agenda for August 13th Meeting
At Middletown Library;
Doors open 6:00, meeting at 6:30

1. Show and Tell
2. Membership Report
3. Finance Report
4. Elwyn Field Experience

INSIDE THIS ISSUE

Minutes of the Propstoppers Model Airplane Club July 9th 2013 at the Middletown library

Call to order took place at 6:30 PM by Vice-President Jeff Frazier
Roll call by membership chair Ray Wopatek showed 16 members and one guest present
Minutes of the June meeting were accepted by the membership
Treasurer's report was presented by President Dick Seiwell.

Show and Tell:

Al Tamburro showed two OK Herkimer 29 glow engines from about 1947. He described how the engines were tuned and how well they functioned. He had always dreamed about one as a child and got them recently from eBay auctions.

Old Business:

Dick Seiwell asked if we would like to have grilled items rather than sandwiches at the September picnic. The group preferred to try the grill. Dick also proposed that the picnic begin at 3:00 PM to allow flying in the later part of the day.

New Business:

Jeff Frazier proposed that Ryan Sherman be appointed as an auxiliary safety officer for Christian academy field. This was approved.
Adjournment took place at 7:30 PM.

Dick Bartkowski, Secretary

Calendar of Events

Club Meetings

Monthly Meetings
Second Tuesday of the month.
Middletown Library
Doors open at 6:00, meeting at 6:30 pm.
Next Meeting; 13th August

Tuesday Breakfast Meeting
Tom Jones Restaurant on Edgemont Avenue in Brookhaven. 9 till 10 am. Just show up.
Flying after in the summer at CA or Elwyn Field 10 am. Weather permitting.

Regular Club Flying

At Christian Academy; Electric Only
Monday through Friday after school till dusk
Saturday 10 am till dusk
Sunday, after Church; 12 pm till dusk
At Elwyn Field; Gas or Electric
Monday through Saturday 8 am till dusk
Sunday 12 pm till dusk

Indoor Flying

Wait till the Fall!

Special Club Flying

Saturday mornings 10 am
Wednesday Helicopter evening in summer
Thursday evenings in the summer
Tuesday mornings 10 am weather permitting after breakfast.
Check our Yahoo Group for announcements;
http://groups.yahoo.com/group/propstoppers/

Beginners

Beginners using due caution and respecting club rules may fly GWS Slow Stick or similar models without instructors at Christian Academy Field. The club also provides the AMA Introductory Pilot Program for beginners without AMA insurance.

Propstoppers RC Club of Delaware County, Pennsylvania.
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At the Fields

Marvelous days at Elwyn, well, mornings, as we did it after our regular Tuesday breakfast. Here are some railbirds.

Larry Kuzmin with grandson Evan, a great flyer.

We had a dozen members out to Elwyn after breakfast on a recent Tuesday. So far the field is fine for morning flying as the sun is out of the field of view and the "runway" more than adequate in terms of length and width and even orientation. Turns out the railbirds can sit at the two Elwyn provided picnic tables in the shade. You can even pilot from the shade too. We fly over the farmer's crops, but no harm no foul.

So let's declare it an adequate field and get on with the enjoyment.

Of course, CA field is magnificent as usual.

By the way guys, we get a continual stream of prospective new members and they all have a hard time finding flyers at the field. How about sending a note to the Yahoo group that you are going out and would like company.

Dave

Test Flying

Test "Flying" Al Cheung's Apprentice on Floats.

Ryan Shurman's Extra 260 Problem

Ryan bought a 79 inch span sophisticated Aeroworks Extra 260 converted from gas to electric. We showed pictures of him with his model in last month's newsletter. It was the occasion of his first flights and the results scared him. At the bottom of a power off loop the model suddenly snaps into an un-commanded right roll. Strangely, it doesn't exhibit this behavior power-on. Note that this model is flown with a 22 inch prop, probably a significant factor in exploring the problem and its correction.

We discussed the behavior at the field and I opined that the force required to rotate a twelve pound airplane in a fraction of a second had to be substantial. Further, such a force could only come from the wings. I suspected the right wing was stalling, but why only power off and why only to the right.

A sudden stall like that sometimes comes from the leading edge being too sharp, and the power on / power off difference could come from the stall originating at the wing root where the large propeller could be holding the flow attached power on.

Another possibility is the right and left wings have different shapes that affect the aerodynamic performance. Ryan subsequently switched wings right for left and flew again with similar results; ruling out this possibility.

Some suggested it might be from a differential elevator input caused by some split command between the two separate servos which drive the two elevator halves. Ryan carefully examined the radio setup and could find no such problem on the ground. But could there be something happening in flight?

But you have to find the cause if you are to fix it and I suggested some flight tests with wool tufts and an in-flight camera to explore the flow fields during the maneuver, and this we did.

Wool tufts were added to the right hand wing and a keychain camera fastened to the root end looking out.

Ryan then flew the maneuver and here are a few frames we extracted from the critical few seconds leading up to the event. A clear stall! Ok, so why only the right hand wing? And was the tail and elevator control a factor?

A second flight was made with the camera now mounted on the canopy facing aft. The movie from this flight showed the same sudden roll but no anomalies from the elevator control. It was tight and tracked true and the tufts showed excellent flow during the maneuver. So this was not a contributor to the problem. Note this frame was extracted from the video while going vertical over Sweeney's property.

So Ryan bought a pitch gage and determined the right hand wing had about one degree greater incidence than the left. So he modified the wing incidence pin holes in the fuselage to level the wings and flew again.

Was the problem solved? Well, Ryan flew out the flight with abandon, but his confidence completely restored and he continues to explore the problem by buying a new and expensive wing.

But I still think the airfoil is wrong.

Dave Harding

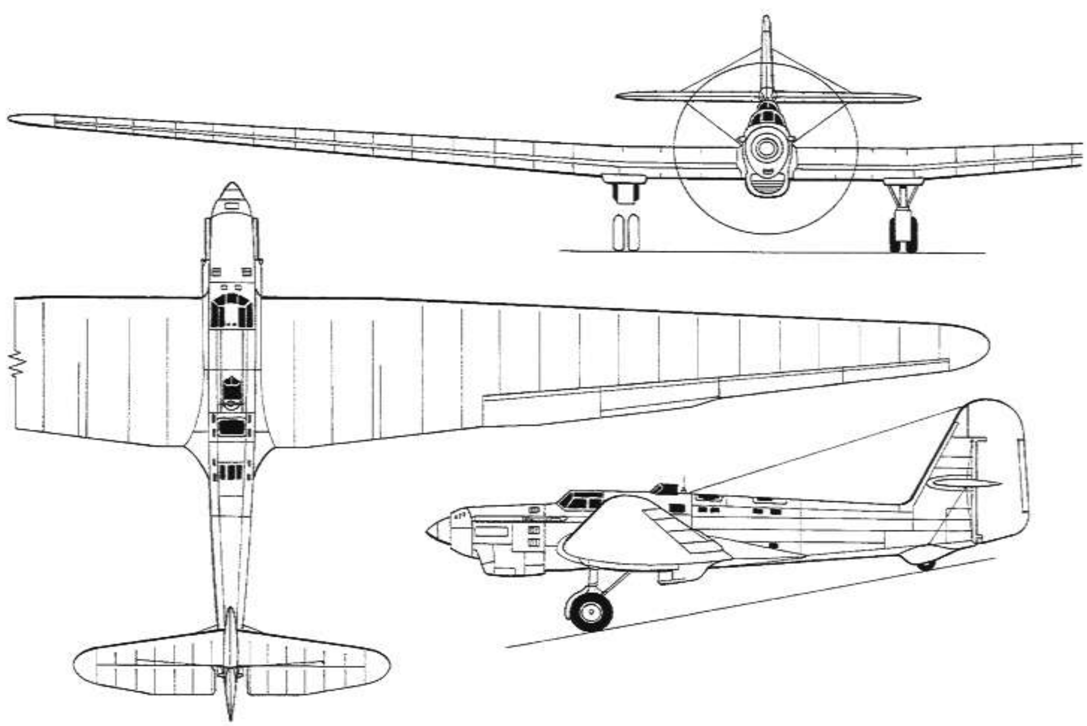
See the movie at; http://www.youtube.com/watch?v=FkmLWkXja4Q

TU-ANT-25 7100 mile Flight in 1937

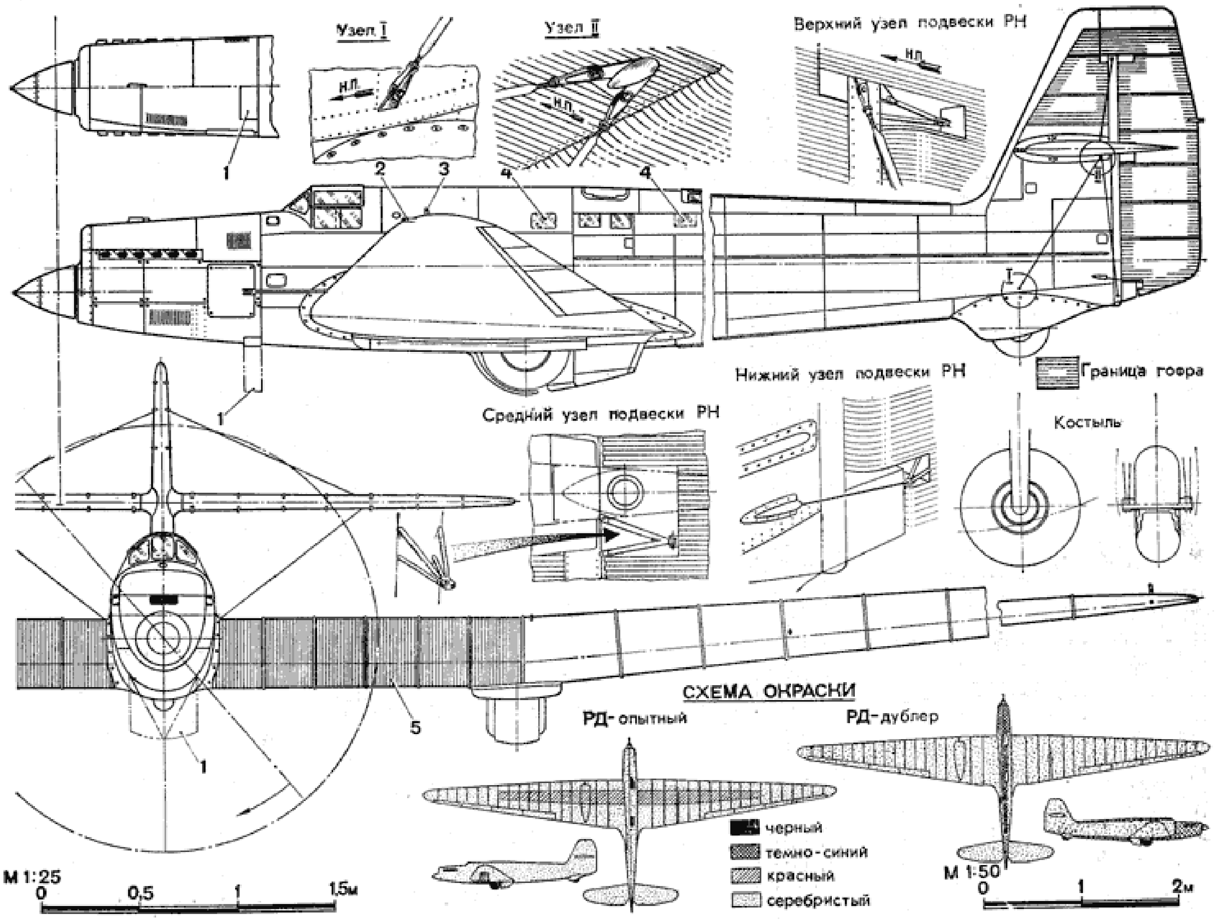
Moscow – San Jacinto non-stop via the North Pole, covered 11,500 kilometers (7,100 mi) and ended in a dairy pasture outside of San Jacinto, California after they had encountered fog conditions in San Diego and as far inland as March Air Force base in Riverside. The landing site is marked by California State Historical Landmark Number 989. The crew flew for 62 hours and 17 minutes between 12 and 14 July 1937. After landing, the aircraft still had sufficient fuel for approximately 1,500 kilometers (930 mi), enough to reach Panama. This would have involved crossing the Mexican border without the permission of FAI sporting officials.

So what you say? Well, we Propstoppers who fly SAM competition have the opportunity to fly a new class at the Champs on the El Dorado dry lake in Boulder City, NV this October. The class is for scale aircraft powered by a Mabuchi brushed "speed 400" motor and any two cell LiPo battery. We are allowed to climb for three minutes then glide. Longest two flights of four wins.

So the challenge is to find a scale airplane with the best aerodynamic characteristics. This usually means high aspect ratio (span divided by chord) and low drag. Models of powered gliders are not allowed. I thought the TU-ANT-25 would be a good candidate, so with several three-views and pictures from the web I made one.

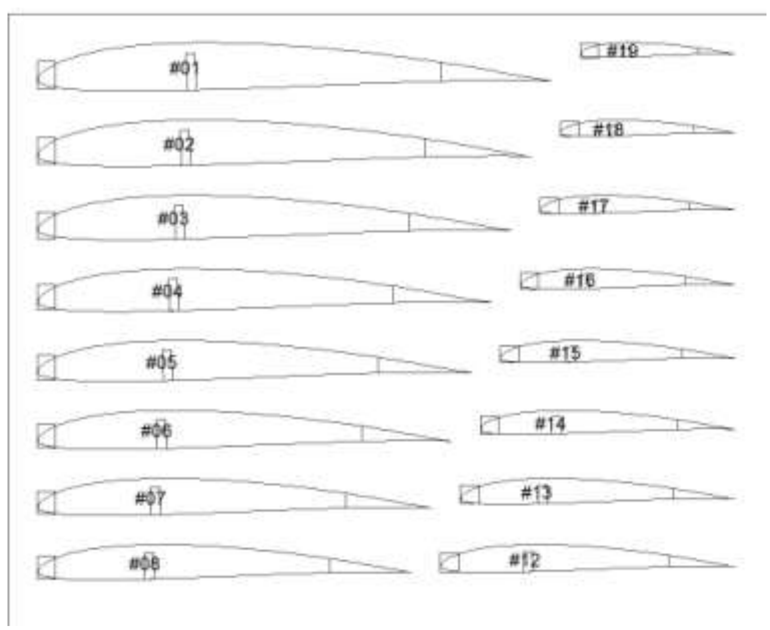


There were at least two versions built, the second with a different engine that allowed a low thrust line.

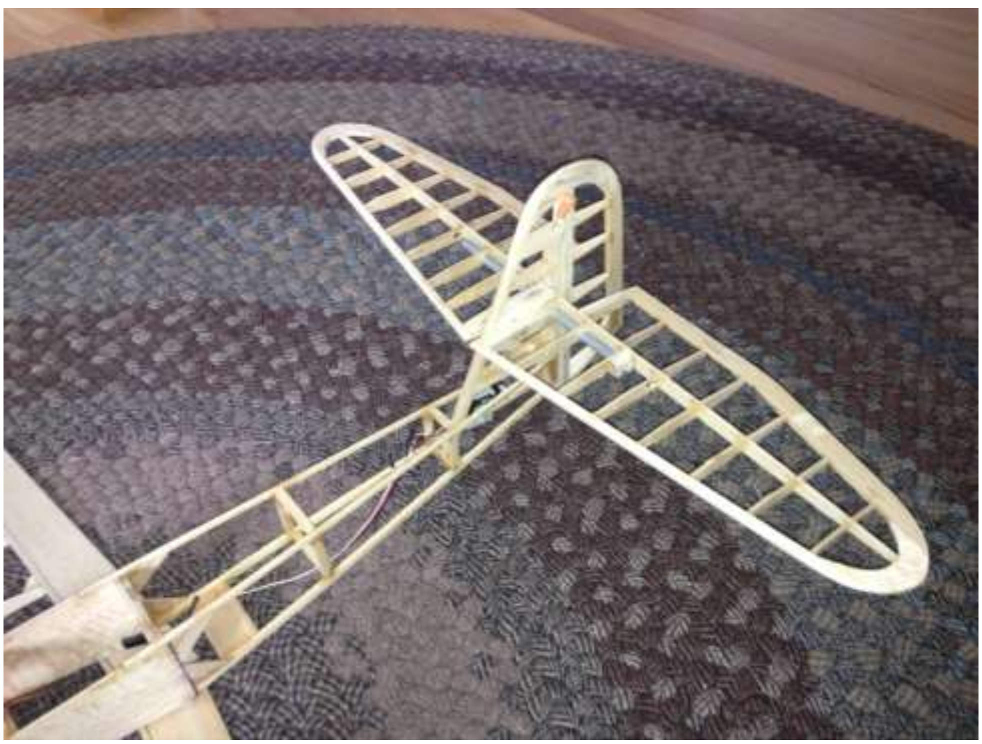


Trying to decipher the notes on this plan I was trying to discover the model number and date of this version. It took a while to figure out the underlined note to the right of center. It looked like the title of the plan, but substituting Russian alphabet letters for "ours" and doing a Google Translate I discovered it means "Color Scheme"! Drat!

Anyway, I imported the 3-view into Corel Draw and scaled it to the required dimension and printed the plan pieces I would need to frame it up. I plopped the wing geometry into Profili and printed out the wing ribs. Cut out the parts and made the airframe.



This plane has a + tail, where the horizontal is attached half way up the fin. This makes for a difficult structural problem especially if you make the horizontal removable for transportation (as I always do). So I decided to make an all flying horizontal where the fin is permanently attached and the pitch change mechanism is contained within. The horizontal stab halves just plug into each other via the pivot tube built into one side.



These very high aspect ratio, highly tapered wings can give handling problems and are prone to tip stall if not properly sorted. So I decided to make some test flights before completely finishing the model. Of course our President always preserves an area of tall grass for such test flights, so off to Christian Academy field for some tests. I had built the model with a dihedral slightly increased from scale and hoped I could control it with rudder only. Our rules do not allow aileron control!

Well, the combination of uncertain flying tail trim settings, insufficient down thrust and inadequate dihedral was a huge handful and in four flights I managed to "hit" the long grass each time,. On the last flight I almost got the trim right but encountered the dreaded tip stall causing the model to spiral in, albeit from a low altitude. No damage though, at least to the model. My self esteem, not so much!

Back to the building board where a few carefully aimed cuts, some CA, a few strips of graphite and a patch of Doculam covering and I am ready for more test flights; with more dihedral.

The airplane with the increased dihedral is still a handful, although it is somewhat controllable. I certainly need more practice as it climbs very well with good stability and limited but adequate control. Then it occurred to me that it may be a wing flutter situation when the nose drops and the speed increases so I did a test flight with two keychain cameras; one looking out along the wing and the other looking aft.

The cameras probably upset the control as their location at the wing root would have interfered with the flow into the lower portion of the fin and rudder. But once again control was hard to establish. Interestingly enough, on final approach, even turning gently, the glide appears to be excellent; maybe the only flight portion where this is evident!

Perhaps it is too high to see what is necessary to transition to a stable glide at altitude.

So with the cameras removed I made another series of test flights and eventually found that with the trim set properly for the glide and a push-over gentle transition to gliding flight the plane flew beautifully. The key is gentle control and a limited, but adequate flight envelope.

So I have been thinking about the rest of the decoration etc. The original airplane had some interesting colors and graphics so tamed I will order some graphics and finish the model to look something like this one. The challenge will be how to produce a digital version of the writing with the Russian alphabet down the fuselage. I suppose I could "cut" it from this graphic.

Dave Harding

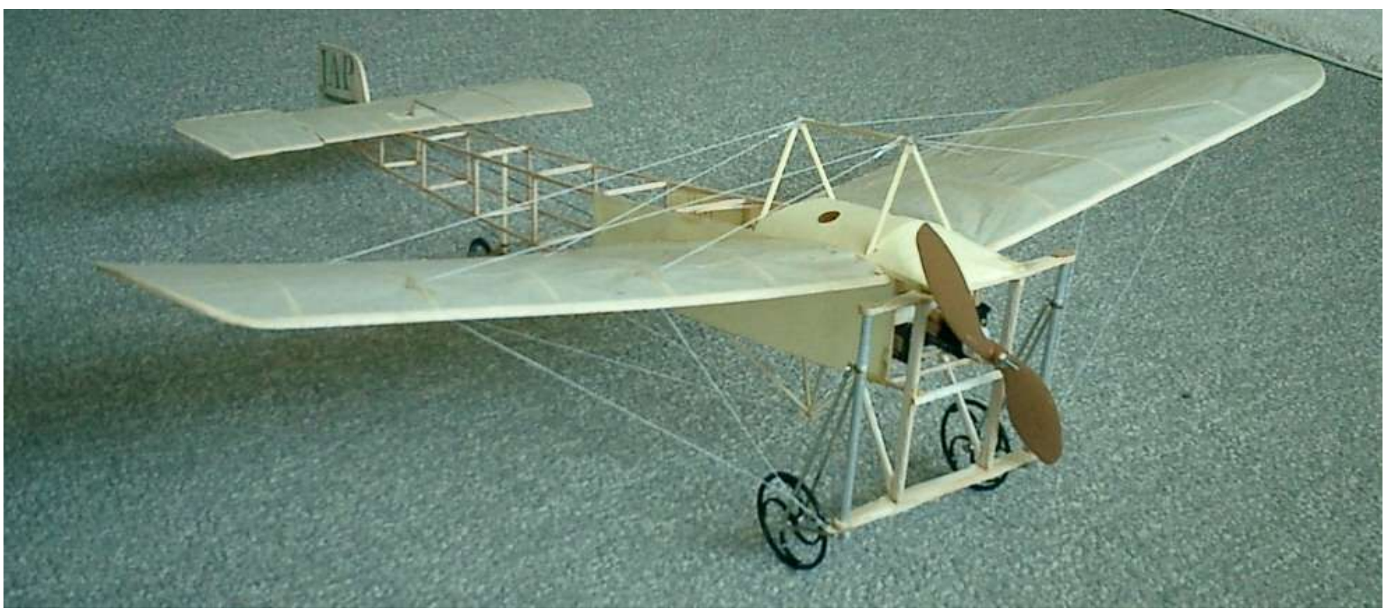
Pre 1914 Speed 400 Scale Duration Contest

Rats, I just heard that one of the SAM good modelers has offered a $100 prize at the SAM Champs (October on the El Dorado Dry Lake in Nevada) for the winning Speed 400 Scale Duration model of an aircraft built before 1914! Hmmmm…. Guess the TU ANT 25 doesn't qualify for that, but what would be the "best" airplane to model? Drat, got the little grey cells working overtime again.

Turns out there are quite a lot of different airplanes that were built and flown before 1914. Here is a list and links to articles on many of them; http://en.wikipedia.org/wiki/List_of_aircraft_(pre-1914)

A group of them that flew quite well were found in my favorite movie "Those Magnificent Men and their Flying Machines". There is even an excellent book about these planes describing each of them in detail with a 3-view plan and photos.

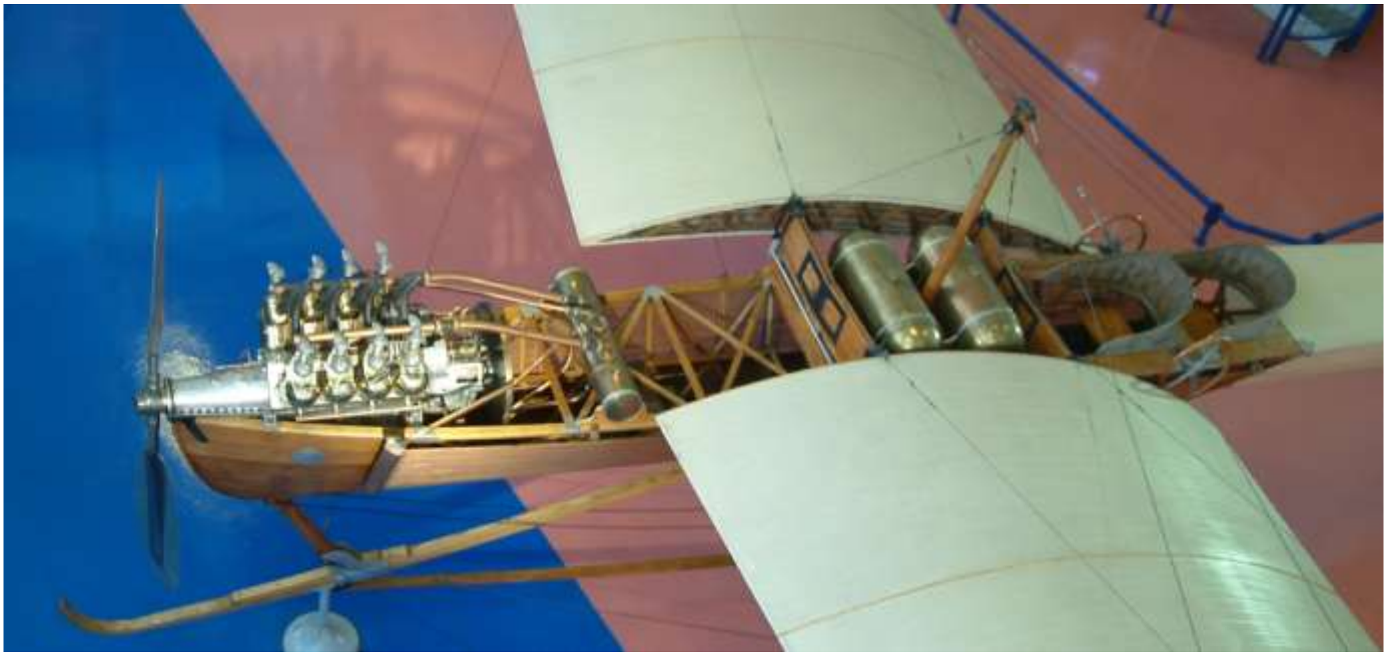
Here is my Bleriot XI indoor model built from original plans for the full size airplane. Interesting model, but not a good candidate for a duration contest, even if I built one to the correct size and power. The drag is simply too high, a factor on most of the early airplanes where they were more concerned with weight and structure with the limited power available.



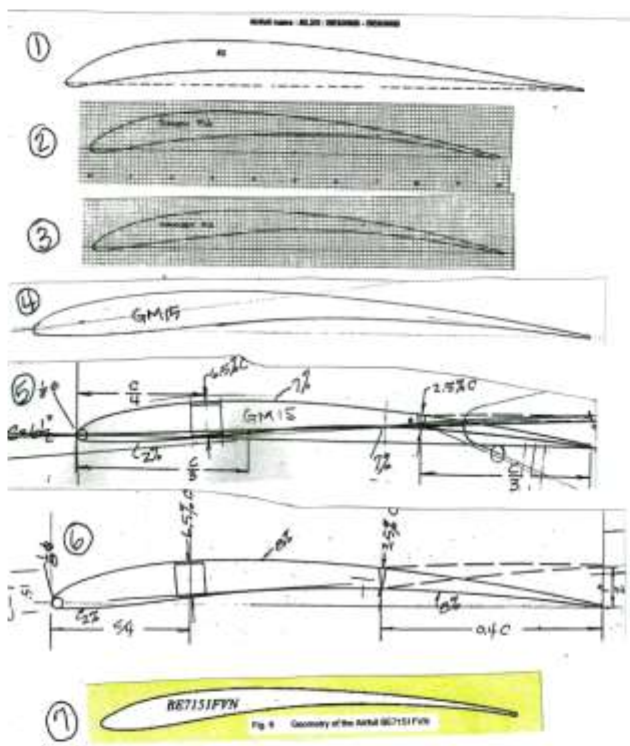
Years ago I built an Antoinette for and "Indoor" "contest" held by Dave Bevan in the return section of the Boeing Philadelphia wind tunnel. Again this was a delicate indoor model, covered with Saran Wrap as I recall. But the basic aerodynamic characteristics are attractive for the contest I have in my sights.

I examined a replica up close on a visit to Paris Musee de L'Air.

I am particularly taken by the wing. It has a fairly high aspect ratio and although the original airfoil is not likely to perform well as it has a very sharp leading edge, but something with similar camber and thin shape might just be perfect for the expected Reynolds Number of the contest model. What airfoil to use? I note the Re is similar to the FAI contest models that have seen great advances in aerodynamics over the years. I recall the Benedek airfoil series used in A-2 gliders as being similar to the Antoinette. Who to ask?



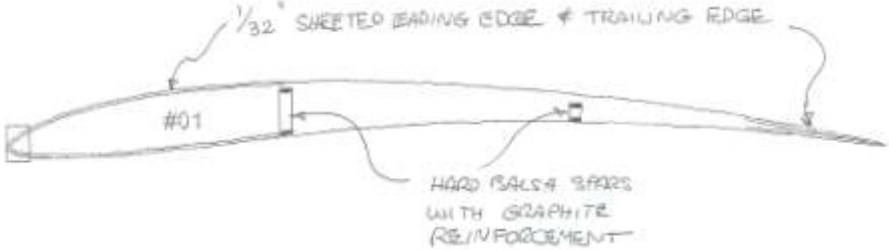
Well, Dave Bevan was the first person that came to mind and I did ask him. Then I remember when we managed the 2010 SAM Champs in Muncie our Banquet Speaker was Gil Morris, a long time US FAI competitor who is still very much in the forefront of technology for these models. (Gil's bio here; http://www.modelaircraft.org/files/MorrisGilbertC.pdf). So I asked him too and he gave me some excellent advice. Here is his answer, but he also told me he had recently built a similar machine, a Taube.



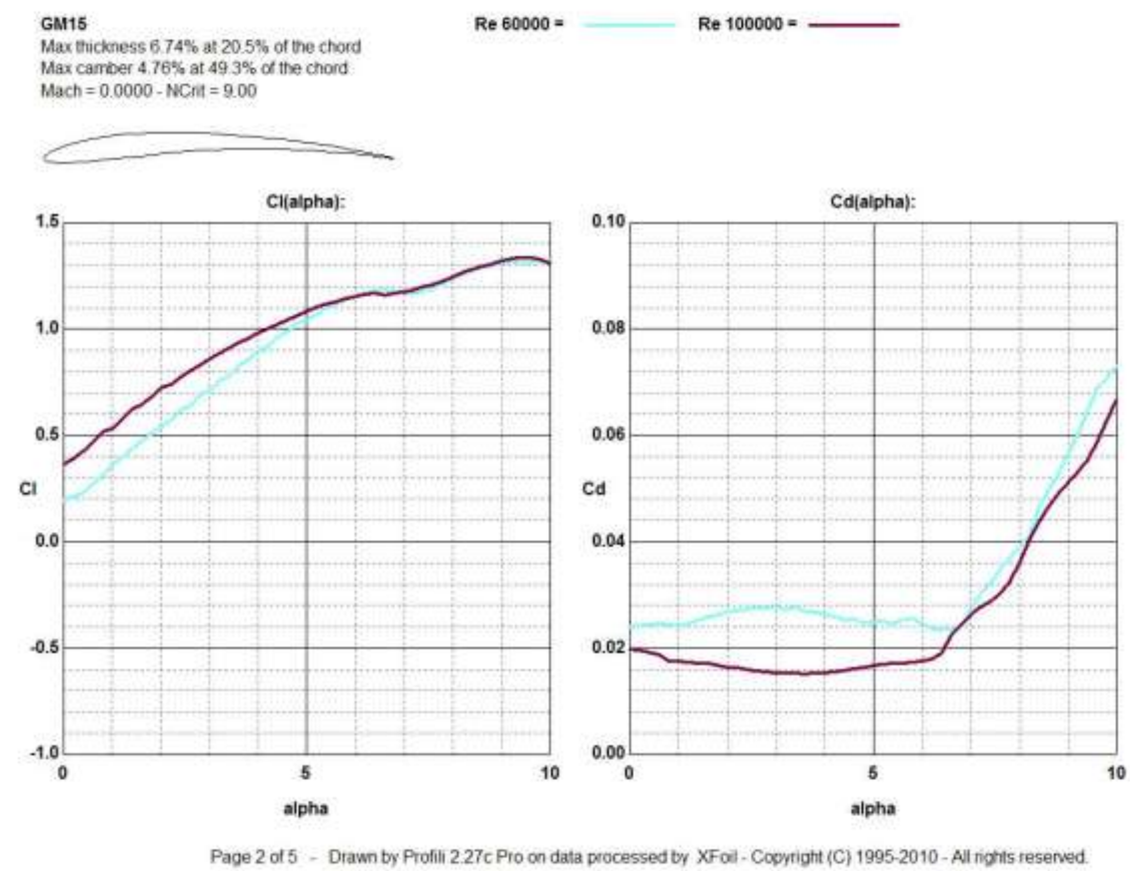
Sounds like you are into an interesting project. Your proposed airfoil selection (1) of attached airfoils is very much like Stamov's airfoil (2) and Makarov's airfoil (3), both highly respected for F1A towline glider operating at 30K -- 40K Re. I think these three are too highly cambered and lack Phillips Entry for your application. I'm partial to GM 15 airfoil (4) and (5) which has been most successful for me in the area of Re 60K in F1C which has a wing loading similar to yours. (5) is the same as (4) but showing construction terms and a re-flexed portion for flapper purposes. (6) is similar but a bit more camber, top and bottom, and a bit heftier. (7) is one of Brian Eggleston's LDA (low drag airfoil) that is getting much attention today and I think rightly so. I think Phillips entry is important to reduce drag as the sailplane guys have learned.

My choice would be (4) followed by (6) if I felt I needed a little more wing torsional stiffness. GM15 is documented in Michael Selig's "Summary of Low-Speed Airfoil Data" and has been used on wind mills, high efficiency ceiling fans and micro air vehicles (MAV's). I hope this is of some assistance. Thanks for asking. I'll see you at the Champs and good luck!
Gil

Fortunately the GM15 is in the Profili library so I can design a wing and print ribs and examine the aerodynamic properties.
Here is how I might build the wing. The challenge is to make it stiff in bending and torsion. The former comes from the graphite reinforced hard balsa spars and the latter from the boxed 1/32 inch sheeted leading edge.



Profili also computes the aerodynamic performance of the airfoil at various Reynolds Numbers, a factor based on speed, chord length and the dynamic viscosity of air. Think as the wing with different flying with different chords as a fixed wing flying in syrup or water. Aero is better at higher Reynolds Numbers but differs for each airfoil. Here is the predicted performance of the GM 15 airfoil at Reynolds Numbers associated with the root and tip chords in cruise/glide flight. The left hand chart is the lift vs. angle of attack, and the right is drag. The dark line is the root chord of about ten inches and the tip at about six. Note the lift performance at six degrees is about the same; a good thing for an untwisted wing. This means they would fly at the most efficient point and beyond that, stall at the same angle too. Note the drag increases markedly beyond six degrees.



But I am getting ahead of myself, first find a plan or 3-view of an Antoinette, and Wikipedia is a good starting point, as was the book I mentioned above. Strangely my usual Google search found little compared to my expectations as this was a successful airplane and the display in the Musee de L'Air provides the basis for a ton of information. Then the penny dropped; I needed to search in French! Bingo; a treasure trove (The French probably still think they invented aviation, which they pretty well did except for one thing; flying!)

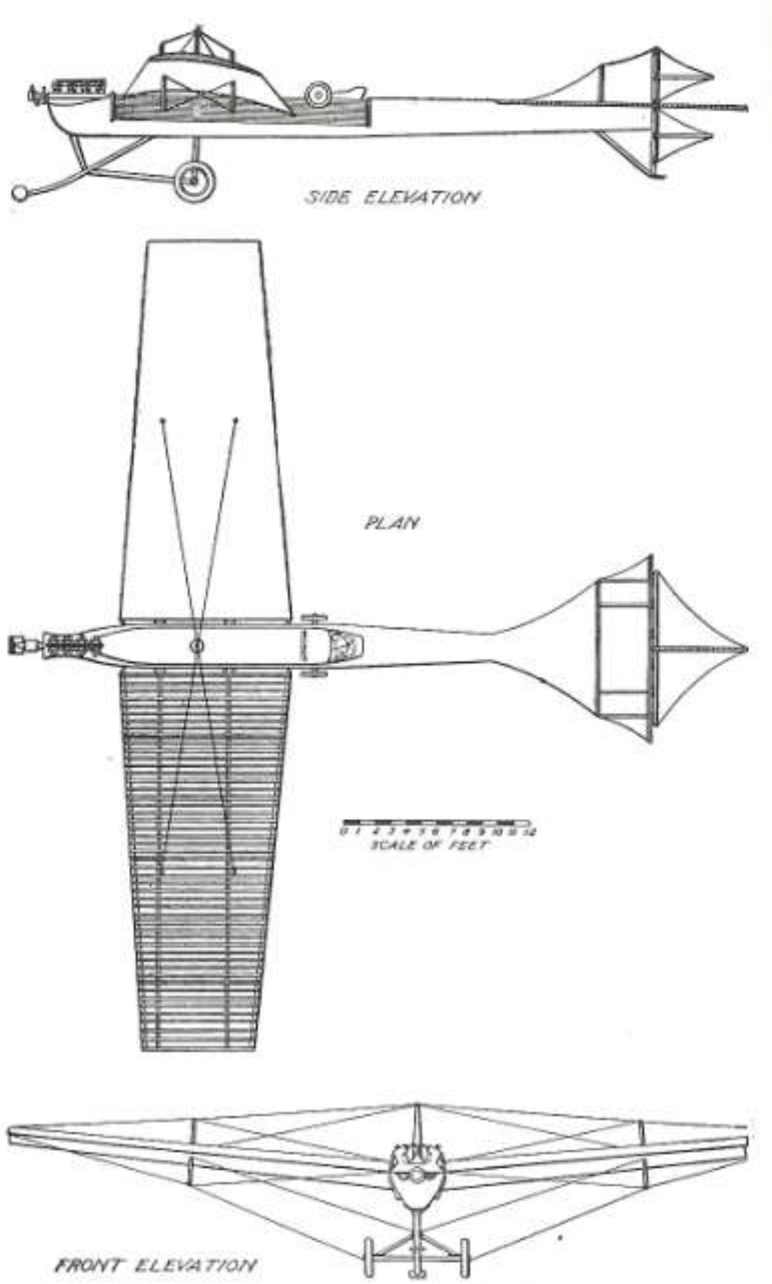


Fig. 28. Details of Antoinette Monoplane

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So, into Corel Draw it goes and the beginning of a plan.
Watch this space for further developments.

Dave

Graphite the Wonder Stuff.

I am deep into a building jag and constantly chewing CA off my fingers, much of it from applying graphite reinforcements to all manner of little structures, well, and some pretty big and important ones too. For instance here is the center-wing joiner on my Boehle Giant, a heavily loaded part if there ever was in a model airplane. Shown here are the "tools"; matching wood parts with Teflon tape on them together with numerous layers of uni-graphite sheets ready to be bonded together into one of the caps.

The materials I use are harvested from out of date materials we use in the aircraft industry. Most of these materials are products called pre-preg. This means they have the fibers arrayed in the directions and density required and infused with epoxy resin. The epoxy is "B Staged" which means it is partially cured to the consistency of chewing gum. The materials are then kept in a freezer until needed at which time they are laid up in a tool, much the way I am doing above, then cured in an oven or autoclave with pressure applied. The oven takes the epoxy back to the liquid state and then it cures. When the materials pass their "use by" date they are discarded. Years ago I found that left out of the freezer the epoxy goes a bit further into the cured state and after a long while it is hard to tell the difference. However, I do not try to re-energize the epoxy as the means of fusing multiple layers, rather I add new epoxy for this job; and it works!

In the picture below I am applying graphite to balsa or pine to make the spar caps for the Giant. Pressure is applied by clamps.

Now the important thing about getting the most out of graphite is to understand where it can apply strength and stiffness and where it can't or needs help. It is immensely strong in tension along the fibers. It has no strength, well little strength cross fibers as in that direction only the epoxy carries the load. Need to do that, well put down two layers at 90° to each other. Really need isotropic strength? Then put down three layers at 60°.

Want to use graphite on spar caps? Good thing to do and very strong and stiff in tension, like in the bottom spar in a pull-up maneuver. But what about the top spar, which is in compression? Now that it a more difficult application because you have this thin stiff strip glued to a balsa or spruce element. The failure mode is buckling of the graphite strip as it will pull itself away from the wood by breaking the glue attachment, which by the way loads the wood across the grain, which is the weakest direction too. What to do? Well, one way to deal with it is to lash the strip to the spar as shown on this highly loaded joiner socket end of the Giant spar. Another way is to sandwich the graphite between two layers of wood. For instance, if the spar is to be 1/4 inch thick sandwich the graphite between two 1/8 inch pieces.

Wing ribs are beam structures that carry the airloads into the spars. Some ribs are subjected to additional loads or are penetrated for joiners etc and this makes them more difficult to build as a strong and light structure. Well, this is another area where a little graphite does wonders. Here I am applying a graphite cap to one of the Giant ribs.

Now if you want something that is strong, stiff and draped over a complicated shape then you use a dry woven material and epoxy, like the Giant cowl shown here.

Now my flying, eating and drinking buddy Dick Bartkowski, believe it or not, is a little sensitive about the evil black stuff appearing below the surface on his models but he knows I have another material which is almost as good as graphite but undetectable over balsa. And that is E Glass uni. I have a ton of that too. I think it is the main ingredient in Boeing composite rotor blades. We tried graphite but it is much too brittle when struck with foreign objects. We found glass epoxy to be extremely impact tolerant. Indeed our offering for what became the Blackhawk program had rotor blades that could continue to fly after being hit by the Soviet 23 mm explosive AAA rounds, but I digress.

If you think you can use some uni material just let me know and I will bring some out to the field.

Dave

Scaling Laws

Back in 2004 the common method of learning to fly RC was to build a 40 powered ARF, like a Telemaster or SIG Kadet and fly away, hopefully with an instructor and a buddy box. But the usual result, at least at some points, was an "arrival" which turned the ARF into and ARD; All Ready Dead pile of sticks. The following article was written at that time based on watching an alternate method of learning being practiced by our very own Dave Bevan. Since most of our current members were not with the club at that time I thought you might enjoy reading it as the timeless physics are very much applicable today.

Scaling Laws, or: Why your big model shatters while my small model bounces.

At our field the other day I met a prospective member who was waiting for one of our instructors for a session with his 40 trainer on dual control. He explained that this was his second model as the first was destroyed when he flew it through a tree.

While waiting he watched two club members flying their electric park flyers and a funny look appeared on his face. He realized that he could be learning the basics flight control on a much smaller, less expensive airplane. One that flew slowly enough to allow errors and recovery, without the expense involved with the same mistakes on the conventional trainer. One of the park flyers was also learning and doing it solo. He made repeated dunks into the long grass beyond our runway. The result was always one of picking up the model, adjusting the wing and launching again for another flight.

How can this be, the bigger airplane would be almost destroyed under such handling. What is going on here?

Scaling Laws, that's what.

Among all of the wonderful laws of physics that bind our universe are sets of laws known as scaling laws. These are the relationships that define the effects that size has on physical behavior. They are fundamental to our hobby as well as our everyday lives.

The primary set of scaling laws of interest to us is sometimes known as Square-Cube laws and their first part relates to how an object's surface area and volume vary with its size.

Area, Volume and Weight

Surface area of an object is proportional to the square of the size.

If we double the size, we increase the surface area by 2 squared;

$2^2 = 4$ times.

This is true regardless of the object's shape.

The volume of this same object, when doubled in size, increases by 2 cubed;

$2^3 = 8$ times.

This is also true regardless of the shape, hence; Square – Cube Laws. Figure 1. depicts these relationships.

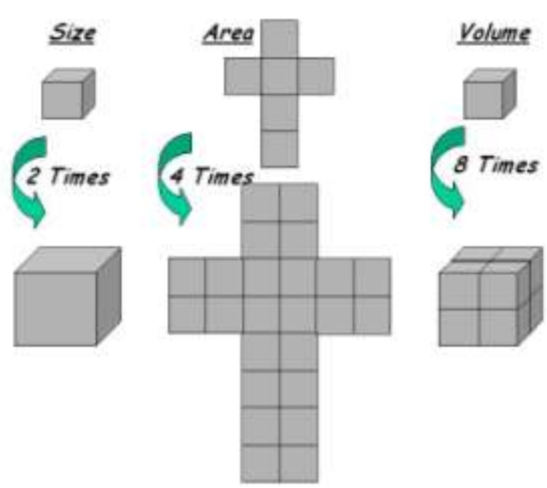


Figure 1. Scaling Effects on Size, Area and Volume

So how is this relevant to our hobby? Well, the first thing is that bigger models are heavier than smaller models, by much the same factors.

But first let me make some disclaimers. What I am about to explain is simplified to aid understanding of the basic physics; however, as I will show later, it is still very close to the real world. In fact, these are the actual methods we use in the real world of airplane design.

So, let's begin with a simple example, a solid balsa model where the weight is entirely from the structure.

Let's assume that we make a 24-inch span model of a Staudacher Aerobat that weighs 5 ounces. We like it so much that we now make a 48-inch model. Wow, how about that, it weighs 40 ounces. Let's see now, if the 24 inch model weighed 5 ounces and I double the size, I should increase the volume by 2 x 2 x 2 =8 times; and since I am still using solid balsa the density is the same so the weight varies by the volume: 8 x 5 = 40 ounces. This is depicted in figure 2.

Great, the scaling laws work. Hmmm, wonder how a really big model would look? Say, twice the 48 inch one; 96 inch span.

So, doing the math, 2 x 2 x 2 = 8 times

8 x 40 = 320 ounces, or 20 pounds.

That is about right for a big aerobat.

But wait you say, I am not interested in a solid balsa airplane; I want to put controls and power in it too.

Ok, so let's look at some real airplanes.

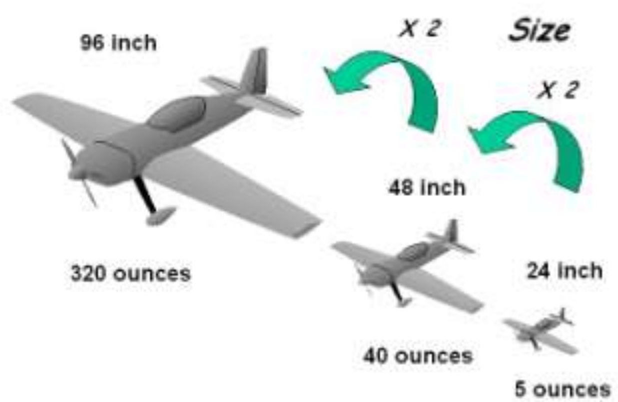


Figure 2. Effects of Size on Weight

Table 1. is a set of 3D / Aerobat airplanes ranging from a very light indoor / park flyer, to a monster 40% Staudacher at 122 inch span.

Table 1. A Family of Aerobats of Increasing Size

Model	Tiny	Mountain Models Tantrum	Gary Wright E3D	Magic ARF	Excite	Eclipse	Lanier Edge 540T	Hanger 9 Extra 300L	Lanier 40% Staudacher
Type	3D	3D	3D	3D	Aerobat	Aerobat	Aerobat	Aerobat	Aerobat
Span ~ Inches	24	37	48	52	61	79	90	97	122
Area ~ Square Inches	225	370	600	725	1100	892	1474	1750	2474
Weight ~ oz	3.6	12.0	48.0	56	112	160	296	384	592
Wing Loading ~ Oz / Square Ft.	1.4	4.7	11.5	11.1	14.7	25.8	28.9	31.6	34.5
Minimum Speed ~ Feet per Second	9	16	24	24	28	37	39	41	42
Energy ~ Foot Pounds	1	23	93	126	332	836	1,731	2,453	4,124

Naturally, these airplanes contain all that is necessary for them to fly under our control. Also, they have the structure appropriate to their weight and performance. Let's plot them and see if there is indeed a trend or relationship between weight and size, figure 3..

Wow, the data seems to plot on a straight-line trend (on log-log scales, but let's not get picky because this is the way we do it in the Big World). We even get an equation for the relationship. This is what we call a weight trend in the airplane design world.

Figure 3.

But wait, the trend equation says that span and weight are not related by the cube power (3) but rather 3.22. This is 9 times for a model of twice size, not 8. Hmm, could this be another factor in the scaling laws? For a start, we know from our experience that we need a stronger structure as we build bigger models. Let's see.

Stress

Lift is carried on the wing spars. The lift, which is distributed over the wing, causes stress in the wing spar caps. For now, just let's say stress is a function of the lift and span (see figure 4.). The lift is proportional to the model weight and the maneuver load factor; g's. In level flight, the lift is equal to the model weight.

The stress in the spar is dependent on the spar cap cross-section area and the depth of the wing. Stress is defined as the load per unit area, pounds per square inch in the US.

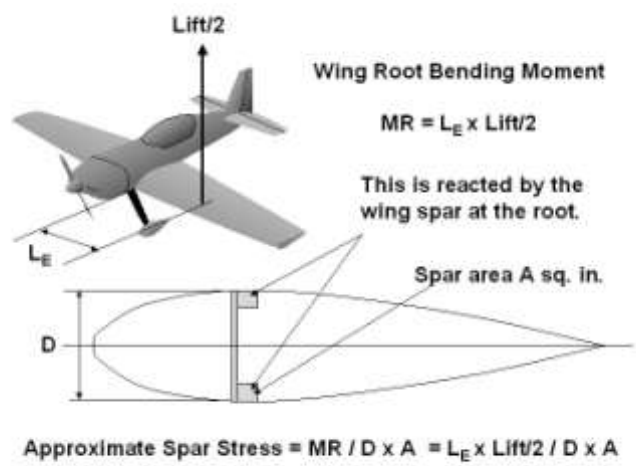


Figure 4. Spar Stress Relationship to Wing Lift

Now let's apply the scaling laws for a model twice the size. Lift is a function of weight and that increased 9 times. The effective span, L_E and spar depth D are a function of size, and that doubled. The spar area is size squared, that increases by 4 times.

So, stress factor = (2 x 9) / (2 x 4) = 2.25

Working all this out we can see that when we double the model size, the spar stresses are a little more than double.

Since the allowable stress, or strength, of balsa is fixed (it does vary with density though) we need a spar material with a twice the strength; like spruce.

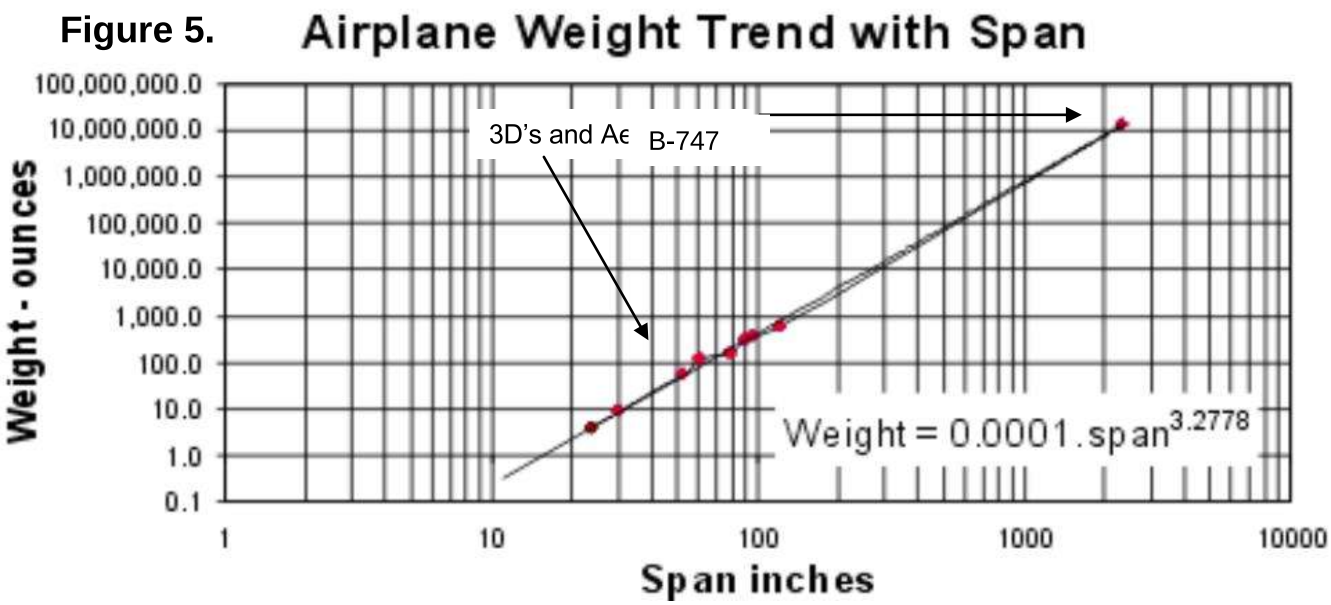
This is why we can't use balsa for spars on larger models (and we can't use spruce on even bigger airplanes). So we have learned that as size increases we must use stronger and therefore heavier materials to carry the loads. This is one of the reasons that airplanes actually get heavier by somewhat more than $span^3$, a factor of 8 each time they double in size, it's more like $span^{3.2}$, 9 times.

You can see this in the trend line through the data from our table overleaf.

Is this real? Check this out, the Boeing 747 fits on the same trend as the models, figure 5, so there must be something to it! Although there are other factors driving the trend above size cubed.

These laws apply in both directions so we now can see why the smaller indoor models may be constructed from rather weak materials, like thin Styrofoam sheet and very light weight balsa.

Figure 5.



Wing loading, Speed and Energy

Ok, so now we know that airplanes get disproportionately heavier with size, but what about the other factors?

Wing loading also increases with size, unless you deliberately design to reduce it, but that puts you on another trend line for lighter models, increase *them* in size and the square – cube laws apply.

Since weight increases by 9 times and area by 4 times, wing loading increases 2.25 for each doubling of size. The consequence of this is higher minimum airspeed.

Lift is a function of speed squared so increasing the wing loading by 2.25 requires speed to increase by the square root of 2.25, or 1.5, or a 50% increase.

Now if we combine the effects of increased weight and increased speed we find that the kinetic energy in our flying model increases by the astonishing amount of approximately 20 times with doubling of model size!

This is the energy you must dissipate when you land…or crash. Imagine the difference in impact between a two-pound hammer and a 40-pound sledge! When you crash, this energy must go somewhere, much of it goes into breaking the model! This is why park flyers just bounce.

Power

Now we started this analysis with a family of 3D Aerobats and the one essential maneuver for this class of airplane is hovering flight, so let's examine the impact of scale on power required to hover.

First we will set a somewhat arbitrary ground rule that the propeller diameter will be 20% of span. This generally matches experience so it is a good starting point. Why is this important? It's because power required to produce a given thrust is proportional to the propeller loading, conventionally known as disk loading in the helicopter industry, it is the measure of thrust divided by propeller swept area;

$$DiskLoadingDL = Thrust/(Diameter^2/(\pi/4))$$

Now the ideal or theoretically minimum power for a given thrust and disk loading is;

$$Power = Thrust/550\sqrt{(DL/2\rho)}$$

Where ρ is the density of air ~ 0.0023 at sea level, thrust is in pounds, disk loading is in pounds per square foot and power is horse power

Notice that power required, for a given thrust, increases with disk loading. Said another way smaller props require more power for the same thrust.

So, again examining what happens to these factors as we double the model size;

Since to hover, thrust equals the weight, power increases by the same 9 times as thrust, multiplied by the square root of Disk Loading. As we saw above, disk loading increases by the same factor as wing loading; a factor of 2.25 and square root 2.25 is 1.5

So, when we double the model size the power required to hover increases by 9 x 1.5 or 13.5 Wow!

Engine Capacity

In our analysis of current 3D aerobats I identified the engine capacity recommended by the manufacturer. Plotting the size trend with capacity we find that recommended capacity increases by 14.7 times when we double wingspan! This is rather more than the 13.5 increase in power. Hmmm, something else going on here. What do you know, another scaling law!

In the real world, the results of a design exercise are markedly driven by the ground-rules. It just so happens that there is another design ground rule with all RC aerobats and that is a noise limit, and the larger models have to make compromises to achieve this requirement.

One of the primary factors in noise generation is the propeller, specifically the propeller tip speed. As the tip speed approaches some fraction of the speed of sound (speed of sound is 1100 ft. per second at sea level) the noise increases markedly. The actual airspeed at the propeller tip is the vector sum of the rotational speed (RPM times propeller radius) and the model flight speed;

$$Tipspeed = \sqrt{(rotationalspeed^2 + flightspeed^2)}$$

Now we already know that flight speed increases with size, so the tip speed must reduce by the amount that the flight speed increases. But the bigger model also has a bigger propeller and at the same RPM there would be a tip speed increase. Consequently the RPM must be reduced by both of these factors.

In piston engine technology, power increases with RPM, within mechanical limits. So, limiting, or actually reducing the maximum RPM, limits the specific power (power per cubic inch or cc) for larger engines (which also tend to be lower specific power, gas-burners). The model designers compensate by using proportionally larger engines. Cranking (oops) this effect into the size trend results in the required capacity increasing by the higher 14.7 times for a twice-sized model.

Maximum Speed

We have seen that the scaling laws drive us to disproportionately more power as we increase the model size so it should come as no surprise that this power increase allows the larger model to go faster. Here is how it works.

The theoretical maximum speed of the typical RC model is set by power and aerodynamic drag. For our "overpowered" models the drag at maximum speed is predominantly from wetted area, skin friction and form factor or streamlining.

We conventionally express this drag in terms of the drag coefficient, Cd. Drag is related to Cd by a reference area. Multiplying the Cd by the reference area and multiplying that by the dynamic pressure calculates the drag. It looks like this;

$$Drag = .0012 \text{ x } V^2 \text{ x } A \text{ x } Cd$$ *Where the units are pounds, feet and feet per second.*

For an airplane the reference area, A, is conventionally the wing area. Notice that Area times Cd is also an area. This is sometimes called the Equivalent Flat Plate Drag Area because a flat plate with this area, placed perpendicularly to the airstream, would produce about the same drag.

Using this concept allows us to estimate the effects of design changes, like retracting the landing gear where you would subtract an area equivalent to the landing gear frontal area from the initial equivalent flat plate drag area.

For a given geometry Cd remains constant with size changes, (excepting the effects defined by that other scaling law discovered by the good Doctor Reynolds. We will ignore this for now.)

For a given power and drag we can calculate the airspeed by the formula;

$$V = 550 \text{ x } Power / Drag$$ Where V is in feet per second and drag is in pounds

Substituting the formula for drag above, we get;

$$SpeedV = 77 \text{ x } \sqrt[3]{Power / (A \text{ x } Cd)}$$ Where A is in square feet.

Now we can estimate the effect of doubling size on maximum speed. When we double the size of the model, the wing area, and therefore the drag area, increase by 4 times. From our prior investigation, when we double size power increases by 13.5 times. Now we see that the speed increase will be proportional to the cube root of 13.5/4

Speed increase factor will be $\sqrt[3]{13.5} / 4 = \sqrt[3]{3.375} = 1.5$

So, when size increases by a factor of 2 the theoretical maximum speed increases by a factor of 1.5; a 50% increase.

I have called this speed increase theoretical because in practice there is another limiting factor, and that is the propeller. In an aerobat, particularly one that is aimed at 3D maneuvers, we select a propeller aimed at maximizing the hover and low speed performance.

Propellers only work well over a narrow speed range. Hover props don't work at speed. However, if we changed the propeller for one that optimizes at the maximum speed, specifically one with the correct smaller diameter and higher pitch, we should be able to come close to demonstrating the speed prediction.

But, propellers are a subject for another time.

Table 2. is a summary of the various scale effects when doubling a model size or designing a model of a particular scale.

Parameter	Multiplier for Size Doubling	Scaling Factor Exponent y (Scale %/100)^y
Surface Area / Wing Area	*4*	*2*
Volume	*8*	*3*
Weight	*9*	*3.22*
Wing Loading	*2.25*	*1.22*
Minimum Speed	*1.5*	*0.61*
Kinetic Energy at Minimum Speed	*20.25*	*4.4*
Power Required	*13.5*	*3.8*
Potential Maximum Speed	*1.5*	*0.61*

To calculate for a specific scale using a scientific calculator; first calculate the scale factor as a fraction ~ Scale in % divided by 100, (or divide the new span by the baseline) then raise that number to the exponent shown by pressing the button for x^y then pressing the number of the exponent from the table. The result is the scaling factor you use to multiply the parameter from your baseline model.

Example:

Applying these factors to our original 24 inch 5 ounce balsa Staudacher and estimating the weight of a 96 inch one:

weight is $5 \times (96/24)^{3.22}$ or $5 \times 4^{3.22}$ which is 5 x 86.8 = 434 ounces or 27 lb.

Happy scaling.

Dave Harding

Maiden Flight of Jeff Frazier's ESM 82" 30cc P-39

Guess he didn't fly it at Elwyn!

I expect he flew it at Lum's Pond where they hold the "Warbirds over Delaware"

Going to fly in it next year Jeff?