Building and Flying Electric Sport Scale

Transcript of Keith Shaw's presentation
to the 1992 Electric Model Fliers of Southern Ontario
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Kingston, Ont.
(There have been changes made to make this easier to read and more organized. Prices quoted are U.S. dollars. Keith lives in Ann Arbor, MI)

What It Takes To Be a Successful At Building and Flying Electric Airplanes

There are four parts to SUCCESS:
1) Good equipment
2) Sensible Choices
3) Craftsmanship
4) PRACTICE

GOOD EQUIPMENT:

There is an old saying, "Buy cheap, buy twice." I know of people who have *tinkered* with electrics for years. They have purchased the cheapest motors they could find, because they didn't want to spend the money on cobalts. They spent their money trying different motors, brushes, fiddling, tinkering, trying to make things work. If you were to ask them how much they had spent trying to get their plane flying, they'd tell you about $150.00!! Compare that with spending $80.00 on a cobalt. My advice is to bite the bullet and buy the good stuff. I have cobalts that I've had since 1978 and I'm still flying them on the original brushes. They are good investments.

The same goes for chargers. Many people are involved with seven cell airplanes. Any charger is going to run $25 to $100. An Astro Flight 112PK only runs a few dollars more and it will charge all the way up to 32 cells. For getting into larger systems, it's a good investment. It, always, has a good resale value. Some of the European charges can run $300 to $400 and I'd think twice before I bought one. Many of the Astro Flight chargers are an extremely good buy. The SR Smart Charger and TRC-6 are also good chargers.

SENSIBLE CHOICE:

A sensible choice is really important. I see a lot of failures in this category. Everyone wants the dream airplane, but they have to go through the steps to get there. At best, you can talk them into a trainer and then their second airplane is a B-17 with retracts! Always the way.

There is a point where you really need to progress and realize that the skills have to be developed and that they are not just going to magically appear. This doesn't mean that you have to stay with trainers forever. The next airplane should be a little bit more complicated and take a little more skill to fly than the first one, but be reasonable in the progression of the steps.

If you want to build a WWII fighter and you are flying trainers, the logical progression is to build some low wing tail-dragger. With this sport plane, you can get practice in taking off and landing a tail-dragger, because that's what most fighters were. A good idea is to take the power system that your dream will need but build a "trainer" for that system. Nominally the same wing area, don't bother to taper the wing if the dream plane has a mild taper. If it is a violently tapered wing, then go with a wing with a fair bit of taper to it. Make the system trainer with a small, typical sport fuselage, easy to build and easy to repair. Make it a tail-dragger and generally the same shape and size of what your dream plane would be. Fly the "trainer" for a while. Make provisions for adding ballast a bit at a time to get up to the weight that you think your scale airplane will weigh. This way you can develop the necessary skills to fly the airplane you want to build. I have, literally, an attic full of "trainers" that I've built. I'm still doing it.

If I've got a plane in mind, that is different from what I'm used to, or I have to solve some problem, I don't build the exact scale airplane. I build something that is close to it; to get all the bugs out of it. Maybe I want to play around with some strange force arrangement or it's a strange configuration that I've not flown before. I throw together one of these "trainers" in three days or a week or whatever, fly it a half a dozen times or so to learn whatever I need. Then I stick it in the attic as a radio test plane. Finally, I build the plane I really want.

I've been doing that for 35 years. These "trainers" are a very good way of picking up the skills you need, or figuring out a "different" airplane.

CRAFTSMANSHIP:

You can save a tremendous amount of weight just by making sure that every part put into the airplane does its full job. If you cut a part that doesn't fit and you use a lot of glue, or whatever, to make it work, you are adding a lot of weight that isn't doing anything better than the original part could have done with a lot less weight. If you spend some time making every part do its job, you save a lot of weight and end up with a stronger airplane.

PRACTICE:

The bottom line is just practice. Get as many hours flying as you can. Fly everything you can. Push yourself. By learning to land carefully, you can probably save half the weight of the airframe. Most the stuff that is in an airplane is to allow it to survive the "occasional" hard landing, (crash). The extra structure's weight is there just so that it can bounce off the ground once or twice. I don't mean really smashing it, just a hard landing. If you think of the model as a full size airplane, most of our landings would have the FAA all over it - "No, you can't fly it again until we check it out!" That is why our structures are so over built. You know the typical "good" landing - good approach, beautiful flare - six feet high; the airplane stalls, drops one wing, does three cartwheels, flips, goes end over end a couple of times and ends on its back. The pilot is mad because he broke a prop! Then he blames the prop manufacturer for making fragile props!

Once you get to the point where you are making decent takeoffs and landings, the structure required to hold the airplane together, through the most strenuous aerobatics, is amazingly light. Fifty percent of the weight, of most model airplanes, is so that it can survive a hard landing. To make it survive really hard landings, the weight goes up 2 or 3 times. When you get this heavy, you have to stick a glow motor on it!

You must decide where you want to go and what kind of model you're going to end up with.

complex		simple
<---	---	--->
complex fuselages custom canopies custom cowlings retracts (6 - 12 months to build)	pattern simple pylon racer sport scale	stiks (note spelling)

Sport planes are really simple. You can dress them up a bit with commercial cowlings, wheel pants, canopies, etc. A few cosmetics can make the simplest airplane look good. A few curves in the tail can make a big difference. These simple changes and additions can make a decent looking airplane out of a stick, one that doesn't look like a stik. (Ugly Stik, Sweet Stik, etc.) You have to decide where your interest is. If you're flying basic trainers, you need to ease into the more involved models.

STRUCTURES:

One of the best ways, I've found, to learn how **<u>NOT</u>** to build airplanes is to look at kit plane crashes and see how things fail. There are kits on the market that have built in failure modes. They put in excess weight and then they put a weak point where it will break.

Look at crashes and try to figure out exactly what it took to make the airplane break that way and then don't do that with your airplane.

When I was flying free flight, in the 50's, we had an old adage; look at what didn't break in a crash and then LIGHTEN that. It must have been too strong, and so too heavy, or it would have broken along with everything else. It sounds funny, but it's something to keep in mind. If you can look over the demolition at your club field, take a look at what survives. I don't think I have ever seen a broken tail. I know guys with walls covered in tails of broken airplanes, mounted like trophies, lined up! You can take that as a lesson. You can back off on the tail structure a bit. It will still hold together. You will often be surprised at just how far you can back off on the structure. The only reason that most planes have all that wood back there is that the kits are designed by guys who learned building kits 30 years ago! Nobody asked questions.

Every time I look at a set of plans, or look through a magazine - I find airplanes that are very simple and have some interesting structural features, some really good , some very bad. I often find some cute way of doing something that is new to me; it's lighter or it makes a part come off easier, when I want it to. I sometimes find these in the strangest places. I always read the free flight columns, especially free flight scale. There are a lot of interesting ideas in them. You have to be a little careful scaling up because we have a large battery pack parked in the middle of the structure. Despite the cautions, there is always something interesting to be found.

Specifics About Structure

These are the three basic premises in looking for good structures. This doesn't just apply to electrics. It can be for 200 mph pylon racers or gliders or anything you want to think about.

1) **TIE THE MOTOR, BATTERY, WING SPAR AND LANDING GEAR TOGETHER** and everything else is a shell going along for the ride. These are the places where forces occur from the outside world. The motor is obvious. The wing spar supports the lifting surface during aerobatics, takeoffs and landings. There are loads induced upon the landing gear and in the landing gear system. There are forces trying to push the gear back and out during landings. Battery mounts should be added, as the battery is a great deal of weight in proportion to the rest of the airplane. The battery has to be kept in place for all normal maneuvers, but there is no way of keeping it permanently in place. If the plane crashes, the battery **WILL** find its way to the ground. If there is anything in front of the battery, it will be struck with the force of a sledgehammer. The battery should be held in place, but provide for it to exit the airplane with a minimal amount of structural damage. It is not a good idea to mount the speed controller right in

front of the battery pack, unless you really want to support your local speed control manufacturer.

Basically, tie all these systems together and then things like the outside edges of the fuselage, the rest of the wing, the ribs, the trailing and leading edge and to a lesser extent, the tail, are "tack-ons"; the forces on them are much less. The "tack-ons" can be, in proportion, of much lighter structure. The central structure is where to invest weight in order to make the airframe stronger, not in the outside shell of the fuselage. You can home in and say, "That's the part that needs strength", and a little extra weight, say a spruce spar instead of a balsa spar, and increase the weight by a few grams but increase the strength by a factor of 3 or 4. The difference between skinning the airplane with 3/32" balsa instead of 1/16" balsa is that the airframe weight increases by 10% but the strength is only increased by .001%. It doesn't make it stronger, but it adds a lot of weight.

2) The second structural mechanics premise is: **TRIANGLES ARE STRONG**. Do everything possible with triangles. Rectangles are weak, but as soon as you make a triangle, then you maximize the strength.

3) The third thing is to **PREVENT STRESS RISERS**. A good example of a stress riser is the foot long, 1/4" dihedral braces at the main spar, the secondary spar, the leading edge and the trailing edge, all attached to 1/4" balsa spars, etc. going out from there. The first time the wing is stressed, the only point that the wing wants to bend is right next to those braces. The entire wing is bending right at that point. (see the free standing arrows in Figure 1) The center section sure won't bend! The wing will fail right where the braces stop.

All that 1/4" ply didn't do a bit of good.

Glues:

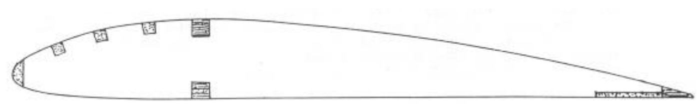
I can't use any CA glues because of really bad asthma, even UFO's. You should be careful around them because you can develop reactions and sensitivities to them.

For foam wings, the glue I have had the most consistent success with is Dave Brown's Sorghum. It's a thin, water-based, cement. I've tried a LOT, but this is the stuff I always come back to. The only exception to this is the high performance F5B type planes that need epoxy adhered sheeting.

Wings:

How the wings are going to be used determines their sturcture. Structures will be very different from a light, floater type glider to a moderately aerobatic sport plane, to a full, fire-breathing aerobatic plane, to a pylon racer. There are different levels of structure needed for the various stresses and strains. (Along with pylon racers, I'd put in the F5B gliders. They are basically pylon racers that have to be thermaled.) You have to decide what the goal is; what you are looking for, and then build the structure to support it.

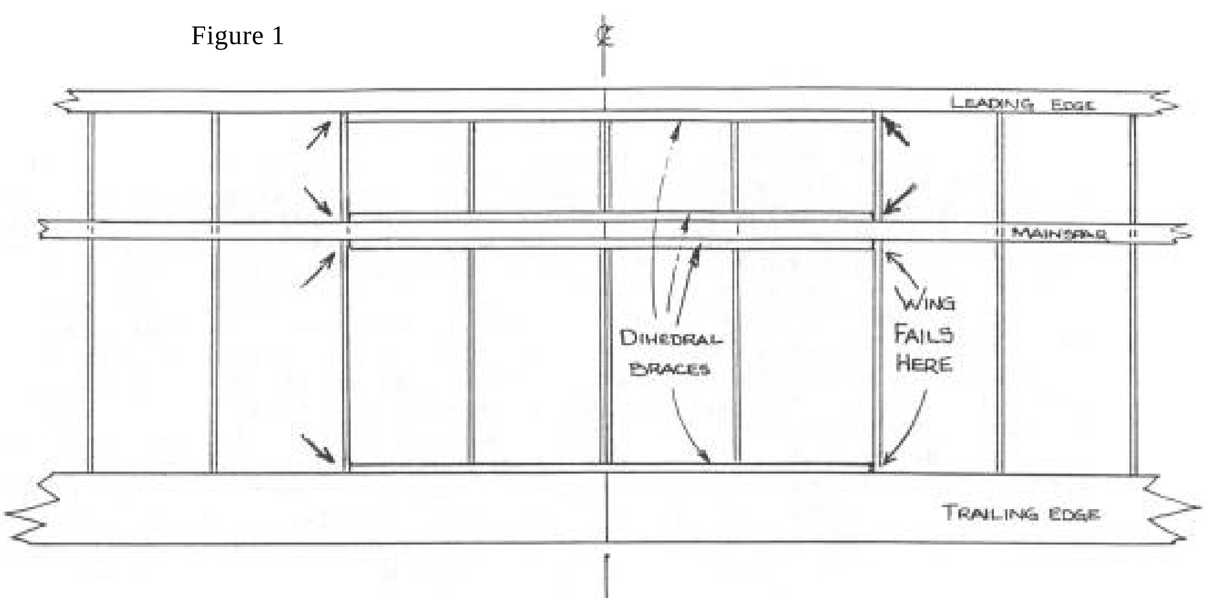
If you are flying a light floater type of glider, say a 2 meter glider with a 6 or 7 cell 05, probably the best wing is a multi-spar wing.



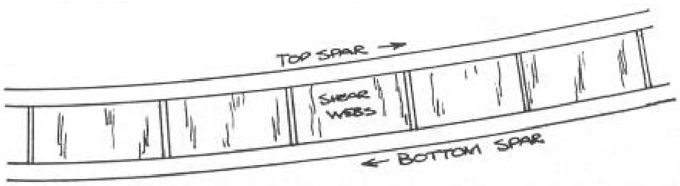
The wing structure is going to be open, keeping the sheeting to a minimum. In designing a floater type airplane, you want the absolute minimum weight. All the plane is going to do is go up and slowly descend, hoping that a thermal is going to run over it and it goes up. A typical 2 meter hasn't any penetration to speak of. Old timers are the same, they just don't have any penetration. The object is to stay up as long as possible with minimum sink. The absolute lightest structure is what is needed. Plan on never putting this airplane into a vertical dive or looping it.

The way to do this is to use a set of spars top and bottom. The best thing to do is to put

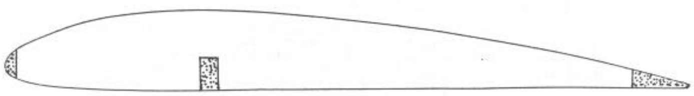
Figure 1



shear webs BETWEEN the spars. An "I" beam is much, much stronger. If you think about a wing, as the tip flexes up, the two spars appear to slide in opposite directions. The shear webs prevent this.



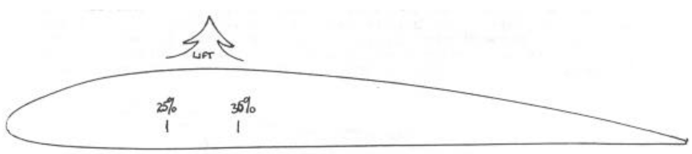
The bottom spar is under tension while the top spar is under compression. All of the materials, typically used for models, balsa, spruce, carbon fibre, are usually 3 to 10 times stronger in tension than in compression. If you want to build a strong wing, you have to think about the materials. Many designers put just a spar on the bottom. That doesn't make sense; it should be on the top. One of the worst airfoils is:



It's probably the weakest wing design. Putting the spar on top helps a little, but not much. Using a top and bottom spar with shear webs and making an "I" beam jumps the strength by factor of 10 at least. The shear webs are really important.

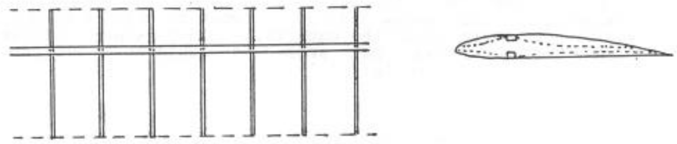
Even light 1/16" balsa will work wonders. Make sure that the grain is vertical. It's harder to cut, but they are stronger.

Put the spars at the center of lift, which, for our airfoils, is around 25% to 35% of the chord. Even though every part of the wing is providing lift, if you add all the vectors, it all magically appears as one big arrow at the 25% to 35% point, so that's where the spar goes.

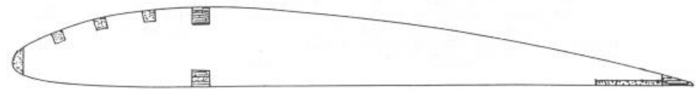


For just strictly bending loads, that's all that is needed. Just that one spar sitting in the middle. There are a couple of problems with having only ribs and an "I" beam spar. Trying to put any sort of covering on when there is no leading edge is just one. We have to stick something up at the leading edge. Everything else, other than the spar, doesn't add strength but is there to maintain the airfoil. If that was all you did, you would find the covering sagging between the ribs and the airfoil between the ribs would be nowhere near the designed foil.

In the rear half, it's not so important, but near the front of the airfoil, it needs something to shape the foil.



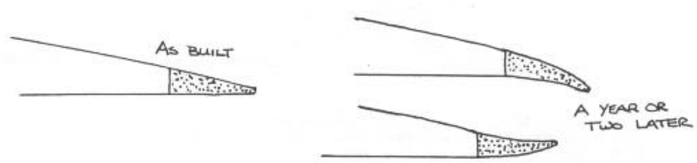
The simplest way to do is called the multi-spar.



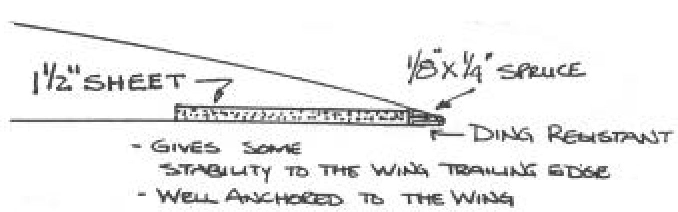
Maintenance of the airfoil is the origin of the multi-spar. Although the "spars" are usually small, typically 1/8" sq. and not real spars, they are just keeping the covering out where it belongs.

There is a little advantage in that very slow airplanes can have problems with air flow separation. The multi-spar wing helps the air follow the airfoil. A very clean airfoil, flying slowly, hasn't got enough air flowing to keep the air attached to the airfoil. Somewhere, about the middle of the airfoil, the air flow is going off making turbulent air flow over the whole wing. It means that, for all the care you took with a nice wing, the air isn't following the airfoil you chose. It's forming its own airfoil. The air flow must stay "glued down". By putting appropriate bumps on the airfoil, turbulence is induced early. It is sort of like a bunch of little marbles that make a little tiny boundary layer and the air flows over them very nicely. The "spars" act as little turbulators and give a nice efficient airfoil. Once a plane gets up to 25 or 30 mph, they don't do anything. At 10 to 20 mph, they help a lot.

The trailing edge is where many people have a lot of trouble. Most kits use great big chunks of triangular wood, butt joined to the back of the ribs. No matter what is done, after about two seasons, the trailing edge is hanging up or down.



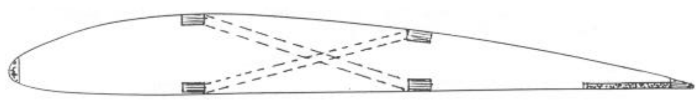
I haven't got the best solution, but what I've always done, because there isn't much strength required to hold the back of the wing straight, is to use a piece of sheet balsa, 1 1/2" wide and then, right at the back, glue on a piece of 1/8" x 1/4" spruce which I carve or sand to shape.



For light wings this works well. When dealing with cap strips, make sure the ribs are cut back so that the caps fair in with the spruce trailing edge.

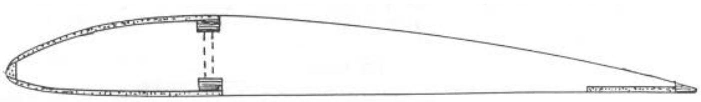
Going faster and playing around with aerobatic airplanes means that, unfortunately, sheeting will have to added. This means weight, but the separation factor of a faster flying airplane, for doing aerobatics or for doing pylon racing, is not so much from bending loads, (loops or pylon turns) - the wing spars still take those - but the faster a plane goes, it sets up a chance for a thing called flutter. Flutter is caused by the turbulence going over the tips and the trailing edge. The whole wing is trying to twist. If you have ever heard it, there is a loud buzzing and, "Oh my god!", shortly followed by the wing going "BOOM!", followed by a bunch of crying.

The next level of structures are to provide torsional rigidity.

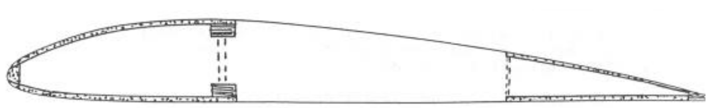


One method is to add a second set of spars and then, somehow, add some structure between them, but this adds a lot of structure and doesn't do that good of a job.

The best way is to add leading edge sheeting which, with some sort of leading edge, ties everything together.

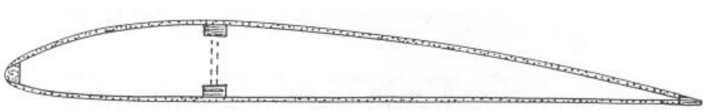


This is a "D" tube structure. It is like a completely closed tube. If you have ever tried to twist a tube, it's pretty hard to do. This is where the torsional rigidity comes from.



If you really want to get carried away, you can close in the rear to form a double "D".

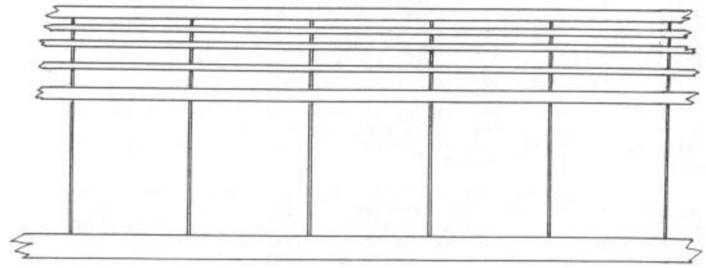
The last step is to sheet the entire wing, which is the strongest. Now the whole wing is acting like a tube.



The front "D" tube is OK for up to 70 to 80 mph airplanes. When the planes start getting faster than that, or doing heavy duty aerobatics with lots of snap rolls, the secondary spar is a good idea. After that, you go to the fully sheeted wing or go to foam with high tech stuff like CF and Kevlar.

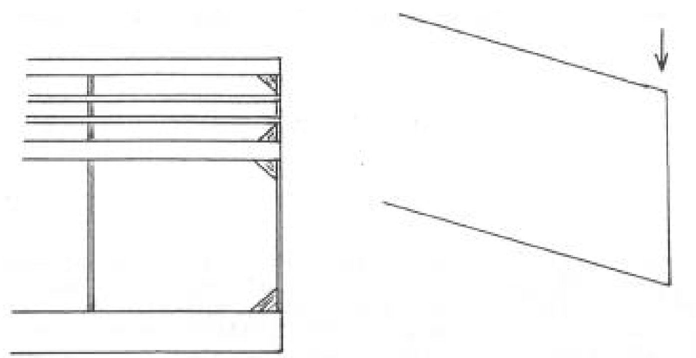
OK, that's the side view, looking at the ribs.

Backing up a bit to the multi-spar wing:



If you touch one wing tip on landing, the whole wing panel will try to parallelogram.

You may have seen airplanes that have made a "nice" landing (!), but every rib bay has a diagonal split and a broken rib at each spar and trailing edge joint. It still looks like a wing, but you might as well take the radio out and put the wing in the garbage. The way you solve that is really simple. Gusset the wing tips. Make sure that the gusset grain goes across the joint.



With the grain parallel to either side, it's not doing any good. As soon as there is any strain on it, the grain will split.

If you have any of those great shelving units for your basement, they use little short pieces of metal on the diagonals. That's about 90% of the strength of those units. That's what the gusset is doing. All the wood in the center of the gusset probably isn't doing anything. You could take out of the middle and just use a little strip of balsa for the same strength.

The other thing you can do is add a lot of 1/8" diagonals. A lot of gliders do that, the Amptique does it. Anything like that adds a fraction of an ounce to a wing but decreases parallelogram failure a lot.

If you use Monokote or Micafilm, both have a very high surface tension. The covering is giving a tremendous amount of strength, preventing the wing from twisting or fluttering. This is why so many gliders can get away with such light structures, even if you dive them a bit. There is a lot of strength in that thin film. Solarfilm, Econokote, Black Baron, things like that,