Basically, it is two pieces of spruce, say 1/8" x 3/8", with a bunch of lightweight cross braces to hold the shape.

All the bulkheads are glued to this. Cut the bulkheads in half, glue all the bottom (or top) halves in place. Then you can set your wing saddle arrangement and stringers. Take it off the board, add the other side's pieces to finish it off.

This technique is really great for biplanes because the crutch is used as a reference for the cabane struts. The mounting blocks can be adjusted, the struts added, top wing mounted and everything jigged straight. Glue on the last pieces and finish the stringers. There's a nice hard surface to work on, and because you build it flat on the board, it is FLAT! The board and crutch are now good reference points to measure everything for the wing. The Gee Bee and the Stearman were done this way.

When building truss structures, spend time on the longerons. It's worthwhile making them from spruce, not so much for strength but, because sooner or later you're going to come in from a nice day of flying and you're going to put the fuselage down on something on the workbench and the balsa longerons will break. If you don't want to go to full spruce, you can go to a laminate of spruce and balsa, especially if the longerons are curved. It's a lot easier to bend two pieces and glue them together than to use one large piece. Use carpenter's glue and pin it down. Once it's built there is no stress transmitted to the other parts. The best thing, when making up structures, is to have every piece remain curved if taken out of the structure. The fuselage side and stringers should remain curved. When parts are pulled together, stressing them with great big clamps, then preloading of the structure occurs, so much that if hit lightly, it could fail because the structure is already close to breaking, due to the preloaded stress.

When working with large bulkheads, many people cut the middle out, forming a ring. No matter how the grain is arranged, somehow it's going to break. Two pieces of balsa could be glued together like balsa ply, but it's a pain.

There is a wonderful material called foamboard. It can be purchased at art stores. It's basically 3/16" foam with index card bonded to both sides. It has no apparent grain. Therefore, great big holes can be cut out of it. It weighs about the same as 3/32" balsa. It's a little thicker. Virtually every single airplane I fly has bulkheads made of foamboard. A great big sheet works out to about $3.00. That is enough to do a lot of bulkheads on a lot of airplanes. The only drawback is that you MUST use RC56 glue. I haven't cut a balsa bulkhead in many, many years. I just don't know how to cut balsa bulkheads without grain fractures.

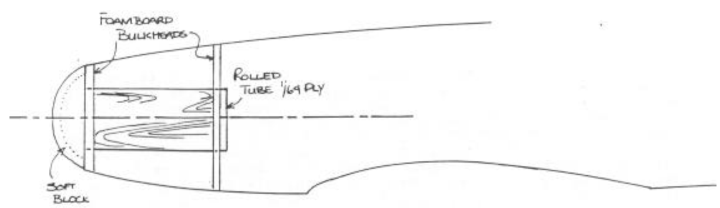
Don't get the plastic covered foam. The plastic covered stuff suffers from some funny failures with age. Remember that foamboard is great material to play with.

Weldbond also sticks to the foamboard. If you use epoxy or typical white glues, it makes a very hard joint, causing a delamination failure. Weldbond All Purpose Adhesive, (identical to RC56), can be purchased from a hardware store. It's a milky white liquid that smells a little like vinyl. It's actually a polymer. You can use that to glue the foamboard to the balsa.

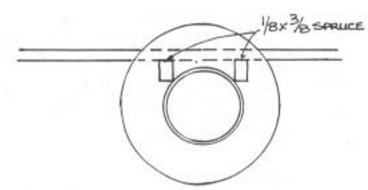
The bulkheads can be cut on a band saw. Just treat it like balsa. On great big airplanes, I've used it for ribs - I mean 14 foot wingspan.

In the forward fuselage there are usually enough stringers for strength. Use some sort of balsa block for the nose with another bulkhead just aft.

I'm a big fan of the rolled up tube of 1/64" ply that the motor is pushed into. I don't usually try to reinforce



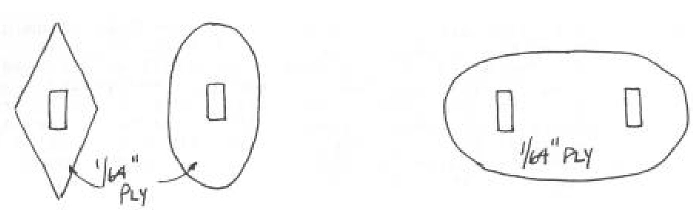
any more than that. Remember to tie the battery pack, the motor, the spar and the landing gear together. With foamboard half shell fuselages, on every bulkhead, somewhere in the middle, like with the crutch, set up a place where there is going to be a pair of lengthwise 1/8" x 3/8" pieces of spruce. This goes back and becomes the stabilizer seat and also ties into the motor tube.



The spruce is also a strong sport for hanging the battery pack.

All of the outer structure is gong along for the ride. It is just there to make the model look like a real airplane. The inner structure is carrying the load.

Since the bulkheads are load bearing, face small areas of the bulkheads with 1/64" ply to help carry the



load. The load goes from the strips to the 1/64" ply and is transmitted across a larger surface of the foam board, tying them together, distributing the load.

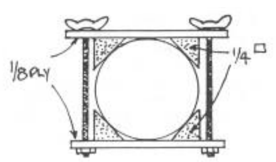
Because electric motors have virtually no vibration, it really doesn't take much structure for the motor. When using a speed controller, the start and stop are smooth. Using an on/off switch limits you to about a 15. Hard starting a 25 with a gearbox and a large prop will probably break every glue joint in the airplane.

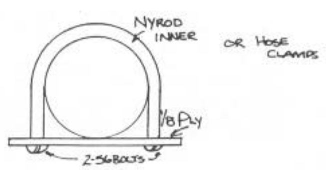
As an example - I was testing the forerunner of the Astro Flight 25 in a pattern plane about 1981. I was coming out of a dive to gain altitude, trying to do what may have been the first vertical 8 with an electric, and at the bottom of the dive, one of the tangs on the commutator popped straight up. The motor stopped in about a 1/2 a turn with a loud CLUNK! The front of the airplane was literally turned upside down. Every glue joint was broken; it was hanging on by a couple of pieces of Monokote and the motor wires. There was a lot of energy in that motor when it decelerated that fast.

A speed controller starts and stops smoothly, so it's not that much of a problem. Trying to hard start some of the larger motors is NOT a good idea.

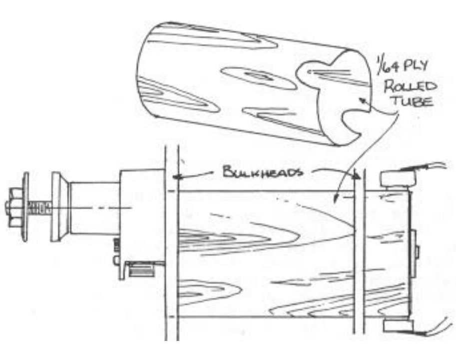
MOTOR MOUNTS:

These depend upon the power levels you are dealing with. When using ferrite can-type motors, almost anything will work.





I prefer the rolled up 1/64" ply tube. I use Astro Flight cobalts in almost every airplane I have. The first reason is quality. The second is the price. They are about 1/2 the price of the European motors, or less. The third being that you can get the parts locally or send it back to "Uncle Bob" and he fixes if up for you.



Make the tube the length of the motor and cut slots for the brush housings. The slots act as an anti-rotation device.

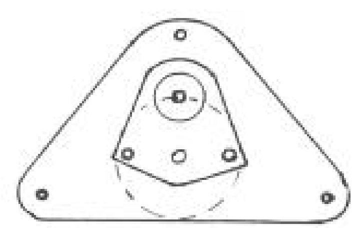
Another trick is to trap the motor with the gearbox. The motor can't move back and forth. Without the gear box, a snug fit is achieved by putting a strip of masking tape on the motor and pushing it into the motor mount for a snug friction fit.

Astro Flight makes a nice little plastic motor mount. It's like a tube mounted on a plastic backplate mounted to a firewall. They work out very well. The motor is held in with a locking screw. For smaller motors, SonicTronics makes a nice little mount that sort of clamps the motor with the wraps. The SonicTronics mount is rated for a 15 as maximum. Originally, it was designed for ferrite 05's.

Obviously, with electric motors, you don't have any vibrations. The great big mounts made like gas engine metal mounts, aren't such a good idea. I once saw an aluminum mount that looked like it was for a .60 glow on the front of an airplane. It had an 05 in it. The motor mount probably weighed 8 Oz. at least. That's too heavy.

When dealing with 250 watts and up, use tubes and other types of mounts. The commercial sport mounts are designed for relatively low power motors.

If the motor has threaded bolt holes in the front, for direct drive, you can bolt the motor directly to the plywood firewall. A different method is used for gear boxes, where you can't bolt the motor in directly. The 60 on the Mew Gull is bolted directly to the ply bulkhead. I also have a supporting bulkhead in the back. (The 60 weighs 24 oz. That's a little heavy for just the forward bolts.) The gear box and motor should be on the same side of the firewall. The motor and gear box should not be separated by plywood because the plywood compresses, which will allow the gearbox and motor to loosen up with time. When the bolts are tightened, there is a lot of compressive force applied. Even worse is a hard spot in the plywood which results in a crooked mounting which is very hard on the gears.



I have, a couple of times, with special purpose airplanes, made something out of 1/16" sheet metal and trapped it between the motor and the gearbox. That was before I figured out the 1/64" plywood tube and trapping the gearbox with it that.

If you believe that you have to make a lot of motor thrust adjustments, either you have the angle between the wing and the tail way off (that's why downthrust is needed), or you haven't learned to fly rudder finesse (that's why side thrust is needed). Putting rudder offset in an airplane is done because you haven't learned how to use your left thumb. With a plane that is trimmed to fly perfectly straight, as soon as it gets out of that straight line, rudder correction is needed.

There are ways of minimizing things so that if you don't use rudder, you hardly see it. But, in reality, you need that rudder finesse to really fly airplanes correctly. Coordinated rudder is what you call it for level flight. Finesse is used when doing aerobatics. During a loop, even the most perfectly built airplane really should have rudder and aileron corrections all the way around the loop. When an airplane is flying fast, that disturbance is only a few inches, but in truth, the corrections still need to be done. The faster the plane flies, the less the correction that will be needed. There is no way of building an airplane, with a rotating prop, and getting it to fly dead straight through all maneuvers and speed ranges.

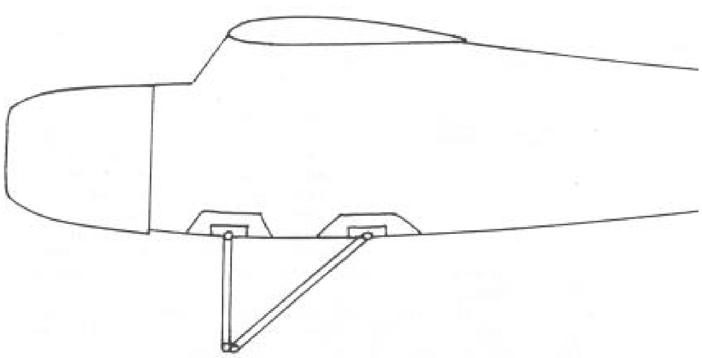
Motor cooling:

The amount of cooling required by a cobalt is not worth considering unless you go out with 16 battery packs charged. Don't laugh. We have a guy, Dave Grife, in our club like that. He shows up with a plane, transmitter, and a backpack and it's ZOOM, ZOOM ZOOM, one flight after another. I went over and touched his motor between flights and it must have been about 400 degrees (Uh, Dave, I think you should let it cool off.) I couldn't believe how hot it got because he never let it cool off; he literally flew continuously for 2 hours, my frequency too.

If you are going to do something like that, yes, try to get a draft to the motor to help it cool off.

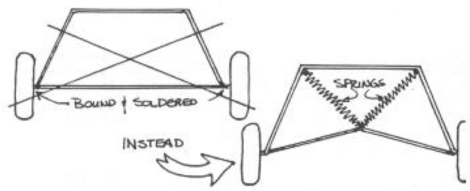
LANDING GEAR: (fuselage mounted)

In many construction articles and kits they try to make a nice light plane and then use a piece of 1/4" thick sheet metal landing gear with razor sharp edges. I don't believe this is a good idea. A better way is to make up two of those little trunnion blocks, like used in wing mounted landing gear, and then mount the gear to the bottom of the plane. If the bottom keel piece is gong through there, glue some pieces up around it to tie things together. Run twin wires out and make one of them the axle.



Like the trunnion block gear, this type also flexes out. Smaller diameter wire can be used than with the torsion bar landing gear of the wing. Use 1/8", 5/32", or 3/16" (for big planes), in wing torsion bar gear while 3/32" or 1/8" will work with this type of fuselage gear. There are all sorts of variations on this and different ways of doing it, but this is a pretty good landing gear.

With this type of gear, the load is mostly taken by the landing gear flexing out and up, but if you hit really hard, it will try to rip out of the fuselage. That's were the reinforcing ply around the blocks goes to work.



Tying the gear together in a triangle defeats the purpose of the landing gear shock absorption. If you do want to tie the gear together, never go straight across. Instead, lash a rubber band or springs to take some of the load. The landing gear shouldn't be completely rigid, but you don't want it to jackrabbit down the field either.

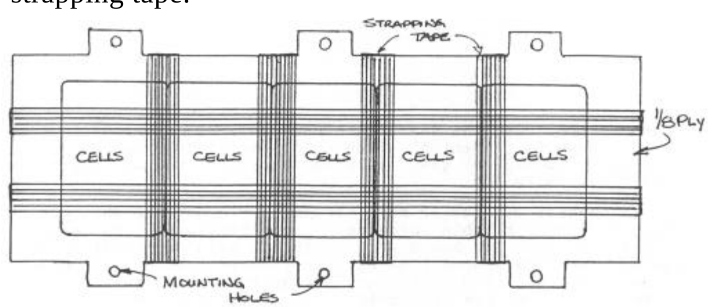
Most sheet metal gear is either too soft, and the flattens on impact, or it is too rigid and doesn't provide shock absorption.

Battery Mounts:

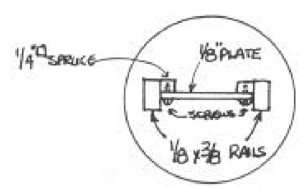
In small airplanes, a piece of Velcro on the balsa fuselage bottom with another on the battery works well on 6 or 7 cell packs. It is not a good idea on 32 cell packs.

A hidden advantage of electrics is that **lead never has to be added** to achieve proper balance. Moving the battery pack about a 1/2 inch can get almost anything to balance. About 1/3 of the weight of the airplane is the battery. It doesn't have to moved far to balance the center of gravity.

Admittedly, I play with a lot of big airplanes, you might have to modify this a bit for small ones. I take 1/8 ply and make a plate and stack my cells like cord wood on it and hold everything together with winds of strapping tape.



Remember those two horizontal spruce rails in the fuselage? In the battery area, I glue 1/4 inch spruce to them to allow the plate to slide in and be able to be moved back and forth. By putting a number of holes in these rails the plate can slide back and forth to change the center of gravity.

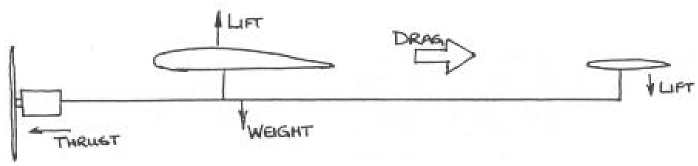


When the correct balance is achieved the plate can be secured with screws.

Fine tuning the CG

As the airplane gets close to its perfect center of gravity, the drag of the airplane drops dramatically, which means it takes less power to fly. Flying an abnormally nose heavy airplane, burns an extra 20% power just to counteract the nose heaviness.

It's the old weigh/lift/thrust/drag problem. Normally,



an airfoil creates drag which we can't get away from, but it also creates a pitching movement, which, with most airfoils, tires to push the nose down. In a glide, a typical flat bottomed wing will try to do a half outside loop. Symmetrical airfoils glide beautifully. For flat bottomed wings, something is usually done with the horizontal stabilizer. A lot of gliders get carried away and stick the stabilizer on at a drastic leading edge down attitude. This acts like up elevator which lifts the nose.

That's all well and good, but in order to get that to work, the center of gravity is fairly far forward, so that the airplane has a chance of flying. It becomes like a beam balance. The wing is creating lift and drag. The tail is also creating lift and drag but the lift is all down. That's the wrong way. The wing is lifting the whole airplane, so that if there is a pound of lift pulling the tail down, the wing needs to lift an extra pound, which increases its drag. Reducing the downward lift at the tail to just a little downward lift, which you need to counteract the wing pitching moment, can get the center of gravity back further on the wing and get the beam balance equation to work more efficiently. The tail is creating less downward lift, therefore less drag. The wing doesn't have to lift as much, so its drag drops. The drag of the airplane becomes reasonable.

An airplane with a lot of negative tail incidence, and the CG well forward, will glide at only one speed. If it goes any faster, it will try to loop. When the plane comes out of a stall, it will drop quite a ways before it recovers.

Where should the CG be? First, set up the CG according to your plans. Then, there are several tests you can make, aerodynamically, to find out what your CG is like. These tests are based on the idea that the angle between the wing and the tail is reasonable. You

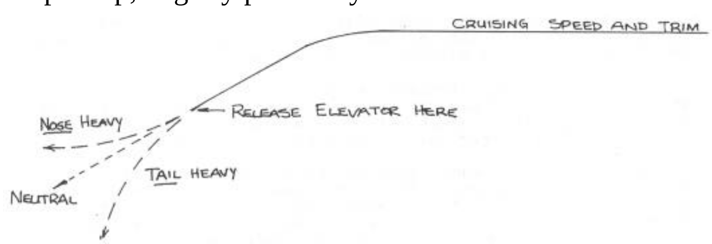
rarely need more than 2 degrees.

It sounds funny, but almost no matter what you do, the airplane will try to fly with the stab level. There are a few exceptions like biplanes.

A plane flying in the 30 to 50 mph range, probably needs 2 degrees difference between the wing and the tail. For a plane in the 20 mph range, it could be 3 degrees. At 100 mph, you only need 1/2 degree or even none at all. I've seen gliders with 5 to 7 degrees. Why they have it, I have no idea.

Assuming even semi-good wing and tail angles, a quick way of finding the optimal CG is to pull back to 1/2 throttle at altitude. Fly well above the minimum glide speed - cruising speed. Make several passes up and down thefield, at several hundred feet, playing with the elevator trim until the airplane flies level with no transmitter inputs.

Leave the throttle alone, but force a 30 to 40 degree dive. When the plane has gained a 20% to 30% increase in speed, (say 50 ft. or so), so that it's accelerating, take your thumb off the stick. If the airplane continues on straight, (hopefully not for very long!), it's at the lateral perfect center of gravity. It is neutrally stable. The airplane doesn't change direction, it just keeps on going. Ideally, I shoot for something that is just slightly trying to pull up, slightly positively stable.



If the stick is released, and the airplane tries to do a half loop, the airplane is very **NOSE HEAVY**. When the airplane picks up speed, the negative incidence, (or slight up elevator trim), acts like up elevator and will try to make the plane loop. (The increased speed makes the trim have more effect.) As the CG is moved back, there is less of a downward load on the tail, so speed has little or no effect.

On the other had, if the airplane dives steeply, it's **TAIL HEAVY**. If the CG is well back, the tail actually has to provide positive lift to balance. When the airplane flies faster, the tail lifts more and the dive is increased.

If the airplane always does a loop on the test, or has a 6 or 7 degree differential, put the CG further back, and reduce the difference to 3 to 4 degrees. That should add quite a bit of duration to the flight because of the reduced drag on the airplane.

Old timers, with lifting stabs, often have the CG around 70%. My Zomby trims out at almost 70% of the cord from the leading edge. It's way back!

Often, many of the old designers didn't mark the CG on their plans, simply because they didn't know either! They would say, "Balance to suit and get a good glide." ("When you've got it, call us and let us know!")

Old timers are very draggy airplanes. There is nothing that can be done to clean them up. Unfortunately, many had a tremendously bad force layout because the designers didn't know a whole lot about aerodynamics. Whether it worked or didn't work depended on which guy stumbled into a thermal. Then, if his plane was green, everyone went off building green airplanes because it took a green airplane to thermal! Few people knew what they were doing back then, so a lot of the old timers had strange force arrangements. Each individual old timer needs its own evaluation and set up, then it's almost cheating, because the original airplane wasn't built that way, so it's no longer really the old timer.

It's always best to get the stab incidence right rather than fiddle with the wing. There are many kits on the market that have the center of gravity in ridiculous spots and have incredible angles of attack. To them, if the plane flies, it's a good airplane. It really depends on what you want to do and what means something. If flying overhead with transparent covering is desired, then you can do anything. If super long flight times mean something, then that means efficiency.

Designing and Building efficient airplanes:

In my articles from Model Builder (July 1987) for designing sport scale and from MAN (Dec. 1991) for twins, I go into great detail about this topic. (note: If back issues of these magazines are no longer available and you need/want them - send me proof that they aren't available - and I will provide copies. Ken) The concepts laid out in the articles apply to both sport planes and scale planes.

I have yet to see an airplane that an electric motor couldn't fly because the prop diameter was too small. In general, we can fly props so much larger than the gas fliers can use, we can come out lighter and beat the performance just on account of the props we can use. A case in point is my Gee Bee R1 which flies fine on a geared 25. Every other one that size, that I've heard of, uses a 60 or 90 to turn a big enough prop and they still crash.

If you do a lot of scratch building and draw your own plans, then you can pick any size you want and pick a power system for it. Another thing that can be done is to find a set of plans for a lightly built airplane and modify it for electric. Another way of doing it is to take a set of plans and just use the outline.

Glow kit conversion: There was a kit manufactured in Germany, a Klemm 25. Every country has a trainer. In the U.S., it's the J3 Cub, in Britain, it's the Tiger Moth and in Germany, it's he Klemm 25, the equivalent of a low wing J3 Cub. It has a huge wing on it, a relatively short fuse, and a big tail. It is a very nice flying little airplane. I haven't built it yet. It's a case where its built for gas, but I can't think of what to lighten. It's such a nice structure and really nice design. It's perfect for electric. Later, I'll go through the parameters to choose the motor to make the airplane fly well.

Using glow plan outlines:

Another case is when you find a set of plans for the airplane you want to build, but it's obviously built for glow engines. It has a 1/4" plywood firewall, 1/4" balsa sides, and foam wing with 1/4" dowel rod. Sometimes it's still worthwhile to get a set of plans just for the outline. If you know what the wing looks like, you've got the ribs, and you've got the fuselage cross section. Then you can say, "I'll ignore their structure and build in a nice light structure that fits." All the sizes and shapes and ribs are done for you. You just have to decide on the wood size.

I've got a set of plans for a Bearcat. My interest in aviation is mostly from 1925 to 1940. Virtually everything I build is a racing plane or aerobatic plane of the Golden Age. I could care less about jets. I did the little ducted fan just as an experiment.

One of the few military airplanes I like was the Bearcat, and the Spitfire of course. I always intended to build an electric model of the Bearcat. I have plans for the Top Flite Bearcat, which is tremendously over-built. I intend to throw away everything and use just the outline.

Scratch building and drawing up the plans yourself:

Another route is to start from square one by taking a 3-view and blowing it up to the size you want. You can take a photo of the 3-view and use a projector to project the airplane onto a large sheet of paper mounted on the wall. Another way is to use a photostat and make an overhead transparency and again project it onto a wall. With the 3-view and some of the cross sections, you can then get some idea of the wing area, wing span, wheel size and prop size.

The plane's actual size may based on how big the back of your car is, how big your work bench is, or whatever. Once the "size" is decided, figure out the span, cowling diameter, prop, wheel size, length of the fuselage and cross section, and most importantly the wing area. That's the thing that's going to provide lift. How much weight you strap on that area determines how it's going to fly and its handling characteristics.

The higher the wing loading, the more your thumb has to be educated and the more careful you have to be flying. Light wing loadings, in general, are pretty easy to handle. The lighter the wing loading, the better, within reason, but we don't have too worry about that as, with our power systems, we are pretty much assured that we won't be too light.

You have to guess at what kind of wing loading you'd be comfortable flying. For light planes, 15 - 18 oz./sq.ft., for a large one and or a small one, 12 - 15 oz./sq.ft. would be better for a nice gentle flier. For an aerobatic or fighter aircraft, 20 - 25 oz./sq.ft. works well. For great big airplanes you can go to 30 oz./sq.ft. The Mew Gull is almost 30 oz./sq.ft. but it works out pretty well because of it's big efficient wing. I didn't intend the wing loading to be that high, but there's a lot of balsa in that fuselage. It's a lot bigger than it looks.

Once the wing area is selected, wing loading can be figured. For sport flying, 20 oz./sq.ft. is a nice number for reasonable performance. Multiply the wing area in sq.ft. by the wing loading in oz./sq.ft. for the total weight in ounces. This tells the kind of weight the airplane should weigh in order to give the handling you're after. All of this is related to take off speed, stall speed, landing speed, and minimum speed to stay airborne. There are other factors, but wing loading is the most important.

If you don't always just want to be flying around level and want some aerobatic performance - roll, loops, etc., these mild aerobatic maneuvers need 50 to 60 watts per pound. If you want good aerobatics - pattern capabilities - you need 70 watts per lb. for outside maneuvers, knife edge, etc. Pylon racers are up over 100 watts per lb.

Multiply the performance level you want in watts per lb. times the weight of the airplane to establish the required power.

A 3 sq.ft. winged plane, at 20 oz./sq.ft., is a total of 50 oz. - just over 3 lbs. That means, at 50 watts/lb., 200 watts gives the airplane those characteristics - mild aerobatics.

How we create the watts needed. (Watt = Volts x Amps)

Our battery packs are fixed in size. If we want a red hot flight, it's a short one, because the current is high, but you get higher performance. The question is how long do you want the thing to fly at full power - this is your peak power, your vertical performance. This power level sets your peak current. For most reasonable airplanes - not biplanes or huge fuselages or 18 zillion rocket pods - with reasonable drag coefficients, and a current draw of 20 amps out of a 1200 mAh pack, you're going to get a 5 to 6 minute flight. If you run 30 amps, it's more like 3 minutes.

Watts are current times voltage. If we want 200 watts at 20 amps for a 5 minute flight, we need 200/20 - 10 volts. Because we get about 1 volt per cell at this current draw, we need 10 cells. A motor chart shows that a cobalt 15 is in about the right range. With 12 cells you could drop the current down to, say, 16 amps, but now, because you're at 16 amps, you might go to 900 mAh cells, save more weight and have the same flight time.

With a draggy airplane, the rule of thumb is to use a geared motor. Dealing with a pattern type airplane with no loading gear and a hand launch, or sleek fuselages or pylon racers, those are obviously direct drive. There is very little drag and the plane is better off with a smaller prop, getting the horsepower that way.

A lot of European motors offer different windings instead of gearing. They don't like gear boxes. They do everything with windings and change the windings more or less to change the "gear" the motor runs in. A motor can be set up for all torque and low rpm and turn a great big prop. If a different armature is put in it, the motor screams at a high rpm but can't use a big prop. Over there, they pick the armature, while we use gear boxes or direct drive.

There are other things to be considered. For a really good aerobatic airplane, leave the landing gear off. The landing gear causes a tremendous amount of drag. I've found the optimum power for a good aerobatic airplane is a 15 size. As far as vertical performance, per weight, per aerobatic, per flight time, it is very good. The bigger airplanes have more impressive vertical, but their maneuvers are bigger and it takes a lot of time for each one. Big planes give fewer maneuvers per flight compared to the 15.

For the 15 size aerobatic airplane, the wing area should be about 350 sq. in. If you want an off the shelf airplane and you don't mind re-engineering the fuselage a little, the Great Plane ElectroStreak with a cobalt 15, twelve 900SCRs and a light radio is one heck of an airplane. Talk about holding the airplane vertical to launch. You get about 3 minute flights at full throttle, maybe 5 minute flights with throttle use.

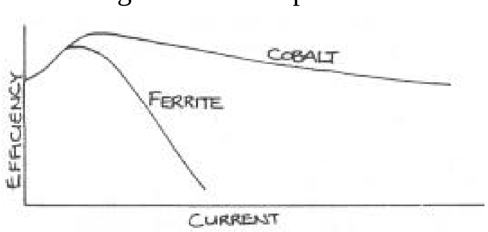
By the time you add a take off and landing, you're making a really aerobatic airplane a real challenge. You're dealing with nothing short of a cobalt 60 with 30 to 35 cells and lots of bucks, just to get the same performance you can get out of a hand launched 15.

When dealing with scale airplanes, to be able to do nice take offs and landings, touch and goes, and modest aerobatics, virtually any size motor will do it. 05's will do it if you're careful, geared 15's will do it, which is a really nice size for a lot of scale airplanes. If you're trying to get some good aggressive flight characteristics, take offs and landing, maybe retracts, you need a 40. A 60 motor is a hard motor to make good use of. It is capable of putting out 1.5 hp, but the problem is that we don't have any ni-cads that can feed if for very long. 1.5 hp out is 1500 watts in. That means that if you are using 30 cells, you're drawing 50 amps! The motor can create it, but the battery pack can only deliver it for about a minute or so. Unfortunately, there is all this horsepower, but it's hard to feed it and keep the flight time. The best way to use this motor is to run wild amounts of horsepower for the vertical rolls, then pull the power back and use 1/4 power the rest of the time. Only when doing the vertical rolls, the figure "M"s and the outside maneuvers do you need full power. 60's are very expensive and it's hard to make good use of them. The only time I use them is when I want to turn a huge prop or when I need a lot of raw horsepower for a high airspeed. The sport 60 in the Mew Gull runs for about 4 minutes at full power at about 100 mph, way above scale speed.

I've actually found that the geared 40 is just about optimal for matching ni-cads to power to performance. A geared 40, running on 20 - 21 cells is about the best route to go. The geared 40 provides achievable power with flight time; with flight speed; with good aggressive performing scale aerobatic flight.

Motors and motor efficiency:

Most cobalt motors run about 75% efficient and the rules of thumb quoted here assume this figure. Most cobalts stay at 75% efficiency as far out as 40 to 50 amps. Ferrite motors, in particular little ferrite can motors, at a little over 20 amps, are down to 40% efficiency. Dropping 200 watts in the front end is only yielding the equivalent of about 80 watts out. That's power like a cobalt 035. The can motor is screaming its guts out, getting red hot and you're getting a 2 minute flight. The cobalt 035 will give the same power for 5 minutes. Be very careful with ferrite motors as their efficiency to power is:



If you push a ferrite motor hard, it never comes back. The magnet is cooked, or the armature, or the commutator, or the brushes, then they fall apart. Remember, buy cheap, buy twice.

I feel that the reason cobalt motors aren't used in car racing is that if they used a lot of cobalt motors, the manufactures of the ferrites would go out of business. They are the ones supplying the events and writing the rules. That's why they don't allow cobalts. You buy one cobalt and run it for 10 years. You can't sell everybody motors 5 times a year or once a race or whatever. End of soapbox message.

Once the power needed is determined, weigh the power plant, battery, and the radio. Work backwards to see how much the structure has to weigh. Look at the airplanes you've built and weigh the structures to see if you can get some idea of the weight of the structures you build. Just a note; if you want a WWII fighter with full skin, all rivets and panel lines, you're not going to make it! The airplane will suffer in terms of performance. With that kind of detail, it will take off, it'll fly around level and look nice, but it won't have any kind of fighter-type aggressive performance.

I prefer performance rather than real detailed scale. I don't mind cheating here and there, using stringers, and building optical illusions for details. I'd rather have the performance. You can't see rivets and panel lines in the air.

Once the motor is chosen, look at the structure and figure out if you can do it. If there's no way, go back to square one and try a different size plane and see if something comes out the way you want.

After a while, you get used to this process and you can predict the motor needed for most airplanes, then you can reverse the procedure and go backwards. You can think; I have a geared 15 and I want 60 watts per pound. That means that I need this wing area for this wing loading, then you can size the airplane for them.

Until you're used to that trick, you can end up with strange results, way over or under horesepowered. It never works out right. When I'm playing around with a new airplane, I always go in the forward direction, because occasionally I get fooled on how much power I need.

Props:

In those write ups, (MB & MAN), there is a discussion about how to choose your props for test flights. I'm not going to get into that here. How to modify props is a little beyond most people. I'll say, at the least, that Rev Up props are, in general, very good. APC props work - I don't think they work as well as Rev Up, but other people rave about them. Maybe they've only used Zingers or Master Airscrew fixed blade props which don't work well for our purposes. The little Master Airscrew props, the 5" and 6" ones are great for small clean airplanes, but the big ones are not. The APC's are reasonable, the Rev Ups are my favorites, the Zingers can be reworked into decent props, but you need to do it correctly. The Master Airscrew Electric Props work well.

I sometimes spend four hours reworking a prop until

I get the results I need and, if it's not right, I buy another one and try again. Once I get one working the way I want it to, I go out and buy another, make a back up, and put it in the flight box so that I have a replacement. A lot of my props are like this.

The single best thing you can do to improve the performance of an electric airplane is to play with the prop. You can change the performance by 30 to 40% with the same watts input. Many times it's just a case of buying a bunch of props and trying out each one. They could all be 10x6's. One of them will probably work a whole lot better than the others. You won't believe the difference. I can't tell you which prop to use because it depends on the airplane. A lot of times, it's just cut and try and experience. I tried to give some outlines in the he MAN article; how to get into the right size and shape prop, so that you are starting with a dozen props rather than 500.

A note on Twins:

In general, twins should be run in series for efficiency, unless you are running tiny 5 and 6 cell motors. They can be run in parallel because they probably only pull 5 or 6 amps each for an 11 amp total. If you try to run two cobalts in parallel at 20 amps each, the total draw on the battery is 40 amps. It's a very short flight time and the rpm will be lower, as the voltage drops at that draw.

Batteries:

Everything, and I mean everything, I fly is with Sanyo SCR's. The reason is that the SCR's are the only batteries that I have found that give me consistent performance and tolerate a relatively casual charge-discharge cycle. They are like a fuel tank, you put electrons in, you take electrons out.

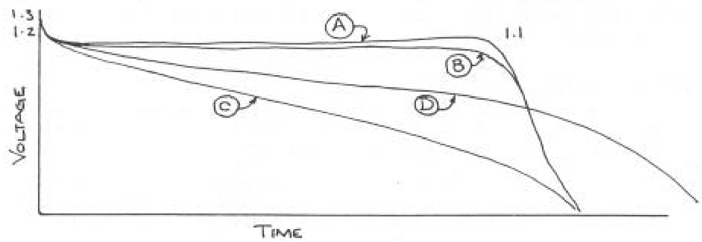
There are several reasons I like the SCR's. They have very low output impedance. That means that when I ask for current out of the battery, in addition to getting the current I want, the battery, which starts out at 1.2 volts per cell, only drops to 1.1 volt per cell, even if drawing 40 or 50 amps. I'm losing only a very little bit, (this is what heats up the battery). Sanyo SCR's do very well in this situation - very little loss.

Something like SCE's, because of their impedance at high amperage draws drops about .6 of a volt per cell. It's like throwing half the cells out. About all they're going to do is keep the fuselage hot.

Wiring:

You get horsepower, yielding performance, with voltage and current. To keep the voltage up you can't have small diameter wiring, high resistance switches, inefficient speed controllers, or high impedance ni-cads. If you are using 10 cells and put a volt meter on the back of the motor and see 8 volts, something is very wrong. A good rule of thumb is 1 volt per cell at the motor at full power. If you don't get this absolute minimum voltage, start looking for where the problem is. Either you have wire that is too small, the wrong switch, the wrong connectors, or something.

In addition to the output impedance, every battery has a voltage profile. That is what the chemical voltage looks like over time as you discharge. At very low currents, virtually every battery curve looks like (A).



Many battery maintenance instruments, like the Ace Digipace cyclers, are set to shut off at 1.1 volts per cell. As we pull current out the battery, we are going to lose a little voltage because of the higher current. The curve will drop a little, (B). SCR's do a pretty good job. They basically stay flat all the way down to the end. It's just like turning a switch off. You know it's time to land when the plane falls out of the sky! With cells like the SCE's and some of the cheaper ni-cads, the profile looks more like (C). You may find the plane landing before you get to the "knee". Even at full power, there just isn't enough voltage times current to fly the airplane. When I fly an airplane with SCE's, the first minute I'm smiling, the second it's okay, the third it's boring, and then I'm scrambling to see how much more I can stay airborne before I have to land. Even then there's still lots of unusable power left over. This applies to high performance airplanes.

With an Amptique-type of airplane, where the current drain is 8 to 12 amps, the discharge curve isn't so bad, (D). Not quite as good as the SCR's but okay. Because the SCE has more capacity for its weight, you do get a longer flight. If putting around, with ungodly long motor runs, slow fly bys, touch and goes, etc. is what you want, the SCE's aren't bad. They are a little finicky to charge. They aren't really as tolerant of over charging. They also have some funny characteristics.

Charging SCE's should be done carefully, at no more than 3 amps. I don't have a lot of experience with them, but that's what the people I know using them charge at. SCR's could care less about how fast you charge them. You can charge at 6 or 7 amps as long as you don't over charge.

AE's are even worse than SCE's. They droop pretty badly. They're the 1250 Magnum size. I won a pack of 7 x 1250 Magnums and took out my Amptique, which normally has 7 x 800 AR's. I did the same flight, took off, flew around, did touch and goes. With the he 800's, I was getting, typically, 30 touch and goes and 12 minutes of flight time. With the 1250's, which are supposed to have much more capacity, I could only do 25 touch and goes before I couldn't get it back into the air. If I had altitude, I could have cruised for some time, but the cells didn't have the voltage to get the airplane off the ground. It's also a little disconcerting to land and the pack is so hot I can hardly touch it. That was in an Amptique which is a low power design. I just don't have too many good things to say about the so called "extended flight" cells.

For carefree ni-cads - simple charging and go fly - it's pretty hard to beat SCR's. Plus they can deliver almost as much power as you need without really effecting the characteristics of the ni-cad.

Charging radio batteries versus power system batteries.

Radio ni-cads should be stored charged. Motor packs should be stored discharged. At the end of the day, I run my packs right down. It's just like running the fuel out of the tank. I don't wait for the prop to stop but I can clearly tell when they are down.

The problem with storing radio batteries flat is that there are micro crystalline growths. With SCR's, it's very unlikely, particularly when given a 5 amp charge. It blows out any growths and the cell acts normally.

I've never had much luck trickle charging radio batteries. I prefer to charger a couple of hours once a week rather than trickle charge.

Balancing Batteries

I never worry about cell reversal because I've never seen it in an SCR. I ONLY use SCR's, so they are all I can address. I never balance packs. I buy the cells in boxes of 20. Whenever I've done tests, there is never anymore than 5% variation. They are all the same, no real bad cells and no real good cells. I don't know where some people are getting their numbers. Maybe someone has already gone through all the cells I get, but I don't think so.

I don't worry. I have yet to replace a SCR and I've been flying them since 1986. Maybe I've had to change one or two of the earlier SC cells, but not the SCR's. When I've had hundreds of flights on high performance airplanes and I cycle my packs, I still get 1.2 amp hours. These are good cells.

Catapult Launches:

Use 10 feet of heavy surgical tubing and 10 - 20 feet of heavy fishing line and some sort of ring. Set the launch ring hook on the line between your vertical center of gravity and where a high start anchor would be. It will be way out in the nose of the airplane. It shouldn't be back where a high start hook would go or the plane will go straight up! The catapult is used just to accelerate the plane. If you pull it back too far, by the time you launch and you're back on the stick, the plane is gone and off the line. If the hook is a little far forward, the plane will drop a bit but it's not much of a problem. Launch with the prop turned off.

About a foot ahead of the hook, put a piece of cloth to make sure the ring drops. When I see it drop, I know that I'm off the line. Its a really nice way of launching almost anything. If you don't feel you can launch carefully or your arm is tired, it's the way to go.