EVERYTHING YOU WANTED TO KNOW ABOUT ELECTRIC POWERED FLIGHT

An E-Book by Ed Anderson
http://www.wattflyer.com/forums/showthread.php?t=31071
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Present on the flying field whenever possible.
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Spelling and Grammar Edited with Annotations
Annotations are in *italics*
By Ken Myers May, 2009

Preface

A number of people have suggested *that* I write a book on the topic of electric flight. I would, but I find the electric field is changing too fast. Paper based books go out of date too quickly. Instead I am going to create a*n online* thread that is my version of an e-book on the subject of electric powered flight. This e-format allows me to provide updates and to answer questions, things I can't do in paper form.

Whether you are a **new flyer**, a **wet fuel pilot**, or a **glider pilot** who wants to add an electric motor to your glider, I hope you find value here. Of course, I will fail to live up to the title. You can't know everything, but I will try to hit the essentials. I am also going to provide an index for your convenience.

The principals of weight, lift, drag, stall and all the other things we know about flying apply regardless of what motor or engine the plane may have. The power systems may differ, and each has its unique benefits and quirks, but the principles of flight remain the same.

For new pilots who have no background, just relax, breathe deeply and read. I have tried to put it all in one place for you. Don't expect to know it all in one reading. After you take your early flights, come back and read again, as you will now have some real life experience to compare to what is contained here.

If you are starting with a *ready-to-fly* (RTF) electric airplane, you really don't need to know all this stuff. However be sure to look at the articles "Six Keys to Success for New Pilots" and "Things to Check On an RTF". I think you will find them helpful.

For wet fuel pilots coming into electric, the first problem is terms and their meanings. Several articles are specifically focused on this need.

I want to change your question from "What is the electric equivalent of a .40 glow engine?" to "What electric power system would be right for a 40 size glow plane?" The first question is VERY hard to answer, but the second is not. I am going to ask you to put aside what you know of wet fuel systems and look at electric power with a fresh mind.

Electric motor systems are both simpler and more complex than wet fuel systems. It is just a matter of looking at them in terms that make sense for electric power and not trying to make them fit the wet fuel framework.

What about batteries? How do I choose between NiCd, NiMH, Li-Poly, and others? We will cover that.

Battery chargers are a mystery too, yet they are an integral part of electric flight. We will cover those.

What about tools to tell what is going on in your electric power system? Yes, we will cover that also.

I will be adding new chapters and topics and will reorganize the articles as makes sense. For example I added an article on the ESC and placed it before the articles on the BEC and LVC, were it made the most sense. Visit again and check the table of contests as you might see a new topic that interests you and it might not be the last post.

If you post a question or a comment, you will be "subscribed" and will receive notification when I post new articles. Don't hesitate to suggest topics that need to be covered.

I invite others who have experience in this area to add their knowledge and become co-authors of this e-book. If you have an area of expertise, share it with us. If you come across a good discussion or a reference source somewhere, post a link to it and tell us why you found it helpful.

You will find my articles and posts rich in links to other resources. Be sure to take a look.

If you have a question, by all means ask, as others will have the same question.

I hope you find this helpful. I hope you will contribute your knowledge as well.

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As the book progresses, I have expanded the range of the discussion beyond strictly electric topics but I have tried to stay within those topics that I feel are relevant to electric flyers. For example the electric "parkflyer" class of planes has a large number of rudder/elevator/throttle planes. Sometimes people get confused as to where the rudder should reside on the radio.

Six Keys to Success for New Pilots

This is not totally unique to electric flight, but since many new electric pilots are trying to self-train, it sort of fits.

Whether you have a coach or you are trying to learn to fly on your own, you will need to be mindful of these six areas if you are going to become a successful RC pilot. After years of working with new flyers at our club, and coaching flyers on the forums, there are a few things I have seen as the key areas to stress for new pilots. Some *new pilots* get it right away and some have to work at it. They are in no particular order because they all have to be learned to be successful.

Wind
Orientation
Speed
Altitude
Over Control
Preflight Check

1) Wind - The single biggest cause of crashes, that I have observed, has been the insistence *of beginning pilots* upon flying in too much wind. If you are under an instructor's control or on a buddy box, then follow their advice, but if you are starting out and tying to learn on your own, regardless of the model, I recommend dead calm to 3 MPH for the Slow Stick and Tiger Moth type planes *and* under 5 MPH for all others. That includes gusts. An experienced pilot can handle more *wind*. It is the pilot, more than the plane that determines how much wind can be handled.

As an example, the wind was around 10 mph steady with gusts to 12. That was strong enough that some of the experienced pilots flying three and four channel small electric planes chose not to launch their electrics. *A* new flyer insisted that he wanted to try his two and three channel Parkflyers. Crash, Crash, Crash - Three planes in pieces. He just would not listen. Sometimes you just have to let them crash. There is no other way to get them to understand.

Many Parkflyers can be flown in higher winds by AN EXPERIENCED PILOT. I have flown my

Aerobird in 18 mph wind (clocked speed) but it was quite exciting trying to land it.

Always keep the plane upwind from you. There is no reason for a new flyer to have the plane downwind, EVER!

2) Orientation - Knowing the orientation of your plane is a real challenge, even for experienced pilots. You just have to work at it and some adults have a real problem with left and right regardless of which way the plane is going. Licensed pilots have a lot of trouble with this one, as they are accustomed to being in the plane.

Here are two suggestions on how to work on orientation when you are not flying.

Use a flight simulator on your PC. Pick a slow flying model and fly it a lot. Forget the jets and fast planes. Pick a slow one. Focus on left and right coming at you. Keep the plane in front of you. Don't let it fly over your head.

FMS is a free flight simulator. It is not the best flight simulator, but the price is right and it works. There are also other free and commercial simulators.

FMS Flight simulator Home Page - Free download
http://n.ethz.ch/student/mmoeller/fms/index_e.html

Parkflyers for FMS
http://gunnerson.homestead.com/files/fms_models.htm

Getting Started with FMS
http://www.wattflyer.com/forums/showthread.php?t=3893

The links below take you to sites that provide cables that work with FMS. If your radio has a trainer port, these cables allow you to use the trainer port on your radio to "fly" the simulator. This is an excellent training approach.

http://www.allthingsrc.com/webshop/
http://www.simblaster.com/
http://www.customelectronics.co.uk/

An alternative is to try an RC car that has proportional steering. You don't have to worry about lift, stall and wind. Get something with left and right steering and speed control. Set up an easy course that goes toward and away from you with lots of turns. Do it very slowly at first until you can make the turns easily. Then build speed over time. You'll get it! If *the transmitter* has sticks rather than a steering wheel even better, but *it is* not required. Oh, and *RC* cars are fun too.

3) Too much speed - Speed is the enemy of the new pilot, but if you fly too slowly the wings can't generate enough lift, so there is a compromise here. The key message is that you don't have to fly at full throttle all the time. Most small electrics fly very nicely at *a* 2/3-throttle *stick position* and some do quite well at *a* 1/2 *throttle stick position*. That is a much better training speed than full power. Launch at full power and climb to a good height, say 100 feet as a minimum, so *that* you have time to recover from a mistake. At 100 feet, about double the height of the trees where I live, go to *the* half throttle *stick position* and see how the plane handles. If it holds altitude on a straight line, this is a good speed. Now work on slow and easy turns, work on left and right, flying toward you and maintaining altitude. Add a little throttle if the plane can't hold altitude.

4) Not enough altitude - New flyers are often afraid of altitude. They feel safer close to the ground. Nothing could be more wrong.

Altitude is your friend. Altitude is your safety margin. It gives you a chance to fix a mistake. If you are flying low and you make a mistake, CRUNCH!

As stated above, I consider 100 feet, about double *the* tree height where I live, as a good flying height and I usually fly much higher than this. I advise my new flyers that fifty feet is *the* minimum flying height. Below that you *had* better be lining up for *a* landing.

5) Over control - Most of the time the plane does not need input from you. Once you get to height, a properly trimmed plane, flying in calm air, will maintain its height and direction with no help from you. In fact, anything you do *with the sticks* will interfere with the plane.

When teaching new pilots I often do a demo flight of their plane. I get the plane to *about* 100 feet, and then bring the throttle back to a nice cruising speed. I get it going straight, with plenty of space in front of it, then take my hand off the sticks and hold the radio out to the left with my arms spread wide to emphasize that I am doing nothing. I let the plane go wherever it wants to, as long as it is holding altitude, staying upwind and has enough room. If you are flying a high-wing trainer and you can't do this, your plane is out of trim.

Even in a mild breeze with some gusts, once you reach flying height, you should be able to take your hand off the stick. The plane will move around and the breeze might push it into a turn, but it should continue to fly with no help from you.

Along this same line of thinking, don't hold your turns for more than a couple of seconds after the plane starts to turn. Understand that the plane turns by banking or tilting its wings. If you hold a turn too long you will force the plane to deepen this bank and it will eventually lose lift and go into a spiral dive and crash. Give your inputs slowly and gently and watch the plane. Start your turn, then let off, then turn some more and let off. Start your turns long before you need to and you won't need to make sharp turns.

I watch guys hold the turn, hold the turn, hold the turn, crash. Of course they are flying in 10 mph wind, near the ground, coming toward themselves at full throttle.

6) Preflight check - Before every flight it is the pilot's responsibility to confirm that the plane, the controls and the conditions are correct and acceptable for flight.

Plane - Batteries at proper power
Surfaces properly aligned *and moving in the correct direction*
No damage or breakage on the plane
Everything secure – *especially the prop adapter and wheels, if the plane has wheels*

Radio –
*Frequency control has been met before you turn on the radio
*A full range check before the first flight of the day
*All trims and switches in the proper position for this plane
*Battery condition is good
*Antenna fully extended
*For computer radios - proper model is displayed
*All surfaces move in the proper direction

Conditions –
*No one on the field or in any way at risk from your fight
*You are launching *or taking off* into the wind
*Wind strength is acceptable (see wind above)
*Sunglasses and a hat to protect your eyes
*All other area conditions are acceptable.

Then and only then can you consider yourself, your plane, radio and the conditions right for *a* flight. Based on your plane, your radio and local conditions you may need to add or change something here, but this is the bare minimum. It only takes a couple of minutes at the beginning of the flying day and only a few seconds to perform before each flight.

If this all seems like too much to remember, do what professional pilots do, take along a preflight checklist. Before every flight they go down the checklist, perform the tests, in sequence, and confirm that all is right. If you want your flying experience to be a positive one, you should do the same. After a short time, it all becomes automatic and just a natural part of a fun and rewarding day.

I hope some of this is useful in learning to fly your plane.

Other resources you may find useful:

Books on RC Planes and RC Flying

http://www.stevensaero.com/shop/product.php?productid=16645&cat=262&page=1

http://www.amazon.com/gp/product/B00071VIGC/sr=8-1/qid=1140260256/ref=pd_bbs_1/103-2556298-8424625?%5Fencoding=UTF8

http://www.amazon.com/gp/product/B0006PBE2M/sr=8-8/qid=1140260256/ref=sr_1_8/103-2556298-8424625?%5Fencoding=UTF8

Important Note About Motor and Propeller Safety
By Ken Myers

An electric motor that is spinning a propeller is an extremely dangerous tool. Always keep that thought foremost in your mind. Give this tool the

same care, caution and respect, as you would when using a circular saw. It is exactly the same type of tool, but without the safety guard required by law on a circular saw! You are choosing to use a very dangerous tool. Use it wisely and with great caution.

The "O" ring that is used to hold some props on some types of prop adapters can break. Prop adapters can "let loose" from the shaft. Shafts can "pull out" of motors. Never allow anyone, including you, in front of or inline with the propeller arc of a spinning propeller. The area in front of a spinning propeller should be clear of objects and walls in case something "lets go" and the prop flies off. Many props will shatter when they hit a hard object sending very sharp projectiles flying everywhere.

Always keep behind the prop. Do not reach over it from the front to hook up a battery, pick up a plane, or for any reason. Remember, it is circular saw with NO blade guard!

Always *remove the propeller to check or install the radio system of an electric airplane. The propeller should only be attached to the motor and the battery connected when the plane is going to fly. If the plane is not going to be flown and the battery is to be connected to check or install the radio system, for safety, the propeller MUST be removed. This procedure HAS TO BE FOLLOWED at ALL TIMES! Never ignore it.*

There are numerous reports, on the Internet and in the print modeling magazines, of planes zooming off of workbenches, charging across floors and smashing into walls, and propellers lacerating fingers and faces, pets, other people parts and worse. While some of these incidents may sound somewhat humorous if the person wasn't hurt, they were in reality only a split second away from being someone's personal tragedy! ALWAYS remove the prop when the battery is going to be connected and the plane is not going to be flown. No exceptions, ever!

There is ***NEVER*** *any reason to hold a motor in your hand, especially with the propeller on it, and turn it on,* ***NEVER****! Whenever the motor is run, it should be secured to the airframe or a motor test stand.* ***Never*** *run a motor in your hand.*

Never lay an electric motor on a work surface without removing all other objects from the work surface first, especially small metal objects like screws and washers that will be attracted to the magnets in the motor. You never want metal objects inside your motor that don't belong there.

The Mythical Best First Plane

As many electric flyers are *also* new flyers, I was asked to add a section on selecting your first plane. The next article is about what makes a good first plane and some of the issues to consider.

Note that I am only looking at electric planes or gliders. I have not taken other forms of power into consideration.

If you run a search on any of the RC forums *such as RC Groups (http://www.rcgroups.com/), RC Universe (http://www.rcuniverse.com/) or Watt Flyer (http://www.wattflyer.com/),* you will find many posts that ask for advice on the best first plane for them to get. The purpose of this discussion is to show that **there is no perfect first plane**, but there are things that can be taken into account to help someone pick an appropriate plane.

Be advised that this discussion will be based on my personal experiences, my bias, my prejudice, my research, what I have observed, and what I have been told. That is exactly the basis that everyone uses when they give you their advice. Take this and mix it in with other advice you trust, as no one person has the answer, only opinions based on *their* knowledge set.

Go and read, so *that* you can build on what you read here. Then make an informed decision and go with it. When you are greeted by the first all knowing guy who tells you that you made a mistake, you will be able to explain your reasons, the considerations and the goals upon which you purchased that plane. And if he doesn't agree? That's OK; we are all entitled to our opinions.

First Consideration - How are you going to learn?

An Instructor - The best, but not the only path to success

If you plan to learn to fly under the close guidance of an instructor, then do NOT go and buy a plane. Go to your instructor and ask what s/he suggests. Learning under an instructor is the best way to learn to fly. That knowledgeable guide is going to take you through planned steps that will impart skill and knowledge. The best first plane is the one that allows that instructor to do that. Your best first plane is the one s/he is most comfortable using.

No one else's opinion matters as you have placed yourself in *the instructor's* hands and should follow their lead. Otherwise, why are you working with an instructor? This opinion comes from a guy who has never worked under the close guidance of a flight instructor but received much coaching from helpful and willing members of the club I joined. Any journey of learning is best started with a knowledgeable guide, and when you engage a guide, you follow them. Enough said about that!

A Coach - Much better than going it alone

A coach is an experienced friend or club member who is willing to give you some time, provide some assistance and point you in the right direction from time to time. However they are not going to take on the close training responsibility of an instructor. They will help, but you will be doing a lot of the learning on your own. This is how I learned.

If you have not purchased a plane yet, be sure to ask your coach(es) for some input as to the plane, or at least the design of the plane.

To be a coach, I feel the person has to spend some time with you on the field. Perhaps they preflight your plane. Maybe they take it up for the first flight to make sure it is OK. They may or may not use a buddy box. The key is that they will give you some help. Having a coach is a wonderful thing.
Things that are a mystery to you can be made clear in a moment by that helpful coach.

Remember that you take on a lot of responsibility, as you will be on your own much of the time and there is probably no formal program that is being followed. If you can't find an instructor, try to find a coach.

An Advisor

I, and many of the people who post on forums, are trying to take on the role of advisor. We can't be there with you, but we can explain a few things, and point you to good sources. We can tell you what has worked for us. A coach is much better, but you can have coaches and advisors, and you can benefit from the multiple sources of information. If you have an instructor, you can ask for clarification from advisors, but you should always take your lead from your instructor. Whether paid or not, they have made a commitment to you. You have to do the same.

On Your Own - *usually the most expensive and time consuming*

Here I mean that you bought something, read the instructions and tried to fly it. Can you be successful? Sure! But the chance of success goes up as you add levels of help. Find advisors, seek coaches and get an instructor if you can. You are more likely to progress faster and your planes are more likely to survive your progress. <u>Flying *RC aircraft* is not a simple or obvious thing.</u> It took intelligent people thousands of years to learn how to do it. There is no disgrace in you taking advantage of some of that previous experience and knowledge. Get some help if you can.

If you have not purchased a plane yet, ask your advisors for some suggestions. ALWAYS ask why they feel this particular plane or feature is important. Sometimes their goals differ from yours and you should factor this into your *decision.*

WING DESIGNS: High, *Shoulder,* Mid or Low

Broadly speaking, airplanes have one of *four* wing locations. They are high-wing, *shoulder-wing,* mid-wing or low-wing. This does not include things like flying wings or delta wings. These don't *usually* have a fuselage in a conventional sense. While there are people who learn to fly on these designs, I don't consider them the first choice for beginner/trainer planes.

Most people will agree that the better choice*s* for beginner/trainer planes are high-wing *or shoulder-wing* designs. The reason is simple, with the wing high and the fuselage hanging below, the plane tends to be more stable and self-righting. This can help keep a new pilot out of trouble.

Mid-wing and low-wing planes are typically less stable as the weight of the fuselage is mounted around or above the wing. These planes are typically more agile and aerobatic than the high-wing *or shoulder-wing* planes. *The* P-51 Mustang *that* you saw at the hobby store is a good example *of a low-wing plane*. It may be a cool looking plane, but it isn't really the best choice for a first plane. That is why the fighter pilots, who flew it in combat, started on something else when they were learning to fly. It might be a good idea if you did the same. They make good second or third planes, once you have mastered the basics of flight.

While using a high-wing or shoulder-wing trainer is good overall advice, the parkzone T-28 or parkzone Corsair, even though low-wing types, make acceptable "trainers," especially with the help of an instructor and buddy box. They are the current "exceptions to the rule."

Dihedral

You will notice that some planes have wings that are basically straight. That is, they come straight out from the fuselage. Others have an upward angle where the end of the wing is higher than the root, the part that attaches to the plane. This is called dihedral. On some planes the upward sweep goes through two or three upward angles. In this case we say the wing has polyhedral, or having many dihedral angles.

Wings with some dihedral tend be more stable and self-righting than flat wings. Wings with flat designs tend to be more responsive and will tend to go where you put them, but also tend to stay there. This means that if you bank the plane to make a turn, you *had* better remember to bank it back to level or it will stay that way. A banked wing will tend to lose altitude if not managed properly. A plane with dihedral in the wing will tend to return to level flight if you release the sticks.

In fact, when I am helping new flyers, if their plane has a fair amount of dihedral, I will often advise them to release or center the stick if they get into trouble. While not always the right thing to do, most of the time the plane will right itself, if it has enough altitude and enough dihedral in the wing. It sounds funny, but sometimes the planes know better than we do when it comes to flying. <u>We have to teach people to let the plane fly.</u>

Whether you are flying glow, gas, glider or electric, having some dihedral in the wing of your trainer will help it to stay stable and level during your early flights. To some extent dihedral will tend to "fight" roll-based aerobatics like inverted flight, knife-edges and the like. However, when you are trying to master take-off, landing and straight level fight, this is *of* less of a concern.

MOTOR LOCATIONS

Many people expect the motor and propeller to be on the front of the plane. However there are many places where the propeller can be located. It can be a pull or push design. It can be in front or in back. While pure sailplanes don't have motors, e-gliders use a motor as a launching system to get into position to look for lift.

There is much to be said for a pusher design on a first plane. On take-off and during flight, the *motor* location may not matter on that first plane. However when you come in for a landing, having the *motor* and propeller high and out of the way can be very helpful. You are less likely to hit the prop and, if you do come in hard on the nose, your repairs are more likely to be restricted to fixing fuselage damage and less likely to involve fixing or replacing the motor and/or propeller.

I don't have a problem with front motor designs, as they are clearly the most common. However, I think that the pusher design has some advantages for new flyers.

POWER SOURCE

Today's RC aircraft are powered in a variety of ways, each having its advantage. While there are good first/trainer planes in each category, it is worth a moment to explore the different ways to power your RC plane.

Gliders

Pure gliders or sailplanes have no motors. They achieve flight through some sort of launching system. Once in the air they may simply glide down or they may be designed for the pilot to look for natural sources of lift such as thermals or slope lift. Clearly you have no fuel cost and your battery needs are extremely modest. The cost of fuel, chargers, motor packs and the like just don't show up.

If this is a thermal glider, you will typically need some kind of launcher. It might be a good arm toss for a hand launched *or* discus launched glider or it might be a hi-start, *which is* an elastic system that typically costs under $100 and lasts for years. If this is a slope glider, then your fuel comes from natural airflow, but you have to find the right location.

Gliders for beginners tend to be in the 1.5-meter to 2-meter, 60-inch to 80-inch range and weigh between 8 and 38 ounces. They typically fly fairly slowly. This slow flight gives the pilot the advantage of having more time to think and react to the plane.

The one down side of gliders is that they don't have the instant power nature of powered planes. Their silent flight and low operating costs can make them very attractive to new flyers.

Electrics

For electric*ally* powered aircraft, including e-gliders, you use a combination of an electric motor and battery system to get your plane into the air. Electric power has become very popular as battery and motor technology has advanced. Today's sophisticated electric planes can rival the performance of traditional fuel powered planes.

Electrics are quiet, clean and very dependable. On the other hand you have the up front cost of battery packs and battery chargers. If you allocate the cost of these items over their useful life, electric flight is quite economical.

Electric power also lends itself to small planes and indoor use. Today you can buy kits, ARFs or RTF electric planes that weigh 1 ounce or less. The broader *category of* "Parkflyer" weighs from 8 ounces to about 32 ounce and can be flown in areas the size of baseball, football or soccer fields. Others require more room.

Some electrics can fly very slowly, which allows them to be flown indoors. Many of these "slow flyers" make excellent first or trainer planes, even outdoors, <u>if you wait for calm weather</u>.

Since you don't have the vibration inherent in *an* internal combustion power system, electric planes tend to be built lighter. Once you add the *power* system back in, an electric plane tends to be similar in weight to comparable fuel planes, especially if the *electrics* have modern brushless motors and lithium *polymer* batteries.

It should also be noted that over the duration of the flight, the available power *usually* start*s* to drop off as the battery pack runs down. So*me* maneuvers that can be done in the beginning of the flight might be difficult near the end of the flight *when using NiCd or NiMH batteries or generation I and II Lithium Polymer batteries*. This drop off will probably always exist, but today's battery technology is making this less and less of an issue as flight times extend from the 5 minute flights of a couple of *decades* ago to the 10-20 minute flights *that are possible* today. *The previously noted performance drop does not happen as much with the most recent iteration of Li-Poly batteries, known as Generation III or G3 types, and the lithium iron phosphate cells from A123 Systems, Inc.*

One last point *concerning* electric power, because it is clean and quite, electric planes can sometimes be flown in locations where fuel powered planes might be denied. This factor alone has probably been a key contributor to the rise of electric power for RC airplanes.

CONSTRUCTION

Today you can select *builder's* kits, ARFs and RTFs made from a variety of materials. Which you choose is a matter of personal taste and your desire to work with that material during a kit build *or assembly* or *when* repairing crash damage.

Balsa wood, *spruce* and *both birch and lite* plywood construction is the tried and true material for traditional kits. *Using just those materials,* you can make very light, strong structures that fly extremely well. Add heat shrink polyester film covering materials, silk or other covering materials *and* you can construct almost anything using simple tools and techniques.

First plane/trainers constructed in this way are fairly resilient, but hard hits can result in breaks that will need to be taken to the workbench to repair. A hard crash can produce serious structural failures.

A variety of foams have become popular. EPS, expanded polystyrene, is used in cups and packing materials. Major structures are often molded from solid foam. It is light and fairly rigid. It can take a pretty good hit. When it does break, it tends to break in*to* large pieces. A little 5-minute epoxy can effect repairs in the field and get the flyer back in the air fairly quickly.

However, repeated impacts can cause permanent dents and damage that must be fixed. Accumulated impacts, that might not bother a balsa plane, can start to degrade the integrity of the foam causing a loss of shape. Again, repairs can usually *be completed* with pieces of foam and epoxy.

There are a wide variety of *builder's* kits, ARFs and RTF planes based on EPS foam. Because most of the structures can be molded to shape, the planes can be built very inexpensively.

Elapor is a branded product of Multiplex. EPO, expanded Polyolefin, and Z foam are similar in character. These *foams* are more damage resistant than EPS, but not as rigid. It sometimes requires more bracing than EPS. These foams *are* more likely tear *rather* than shatter as EPS does.

Using the right glue, each *type of foam* can be fixed quickly so that the pilot will get back into the air quickly. In balance, some feel these are a better choice for models, so this group is growing in popularity. Each has its own special character, but all seem to be a good compromise between rigidity, weight and damage resistance.

EPP, expanded polypropylene, is another popular foam that has been around for a while. It moves further from EPS in that it is less rigid than the rest of the foams. In fact EPP is quite rubbery and tends to be heavier than the other *types of* foams. As such, it needs more bracing in order to maintain a solid wing or fuselage shape. However, for damage resistance, EPP is the king. I have bounced EPP planes off of hard surfaces and sustained no damage at all.

Planes made of molded solid EPP parts tend to be heavier than balsa or EPS structures. EPP is so resilient that it has spawned a new class of full contact combat flying. Popular with slope glider flyers, EPP equipped pilots will intentionally crash into each other to try to knock each other out of the sky. Since little or no damage will result from the crash, the pilot can just re-launch for the next round.

Molded Polystyrene and Polyethylene are also popular. Polystyrene is the plastic typically used in plastic model kits. Polyethylene is the kind of plastic used in plastic milk bottles. Like the foams, these are inexpensive to manufacture and can be quite resistant to damage. More commonly seen in small electric RTF planes, these are growing in popularity.

Other forms of foam and plastic are also being used in first/trainer planes. The *previously* mentioned *foams* cover the vast majority of models out there. Their advantage over wood is *a greater* resistance to damage and ease of repair. Wood remains popular for the light and strong structures it can produce. The foams and plastics open up more options for new pilots.

Which*ever one* you choose is up to you. If you like the idea of building with wood, you will find a wealth of wood *builder* kit *and ARF* based first/beginner planes.

If you want to minimize the build, or minimize the chance of extensive repairs, the foams may be more to your liking. The plastics are most typically seen in ARF or RTF packages rather than kits.

When we look at the electric plane market, we see a much higher percentage of foam and plastic planes as compared to the glow or thermal gliders. This is especially true in the RTF *segment* of the market.

While I have no statistics, I would guess that the sale of non-wood first/beginner planes probably outnumbers wood starter *planes* in the electric market. That doesn't mean that the wood planes are going away, just that the market is expanding very rapidly and most of the expansion seems to be in non-wood construction.

The good news is that you can have whatever you want to meet whatever goals you set for yourself.

Functions or Channels of control - How many should you have?

Let's knock down some myths about *the number of functions or* channels*, as we call them,* and what can and cannot be flown and what can and cannot be used to learn to fly. Today you can buy RC airplanes with one *function or* channel of control and 12 or more channels of control. They can all be flown, and **anyone who says they can't is wrong**. Is that strong enough?

Understand that each *function or* channel is used in some way to control the plane or some *optional* function on the plane. From a flying point of view, we will be focused on <u>attitude control</u>. That is pitch, roll, yaw and speed. Broadly, you can think of them as up *and* down, left *and* right and fast *and* slow. This isn't correct, but for the moment it will do. You can learn the true meaning of pitch, roll, yaw and speed later.

The more *functions or* channels of control *that* you have, the more control you have over the *attitude of the* plane. Duh! The more *functions or* channels of control *that* you have, the more responsibility you have in applying those controls. A 10-channel plane has been designed with the assumption that the pilot knows how to use those controls and has a sophisticated radio system to help manage those channels. Maybe it would be easier to learn if we had a plane that didn't need our full understanding of 10 channels of control or a $500-$1,500 radio system to fly it.

So how _functions_ many is enough?

One - Probably Not

Two - Yes and Maybe

Two Channel Gliders - Yes!

Many gliders are *two-function or* two-channel. Based on their design, you can have very effective control. You can even fly wild aerobatics at speeds in excess of 100 mph. Two-channel gliders can be very exciting and wonderfully enjoyable.

Typically, the channels will control pitch and roll. This can be done with elevator *and* rudder or elevator *and* ailerons. With these two axes of control, we can have excellent command of the plane. Of course the plane needs to be designed properly for the controls it has, but that will be a given here. We are not trying to design planes.

There are hundreds of successful and effective glider designs made for slope soaring, thermal duration soaring, hand launch, discus launch and other forms of flying. Zagi slope wings, Gentle Lady thermal gliders, Gambler discus launched gliders and others are examples of these kind of planes. They can be exciting to fly and can really teach you about flying. When someone tells you that you can't control a plane with only two channels, they are very wrong! Go to the glider field or slope soaring field and you will see all the evidence you need.

Many people feel *that* the best plane to use to learn to fly is a glider. *Gliders* are typically simpler in design, lower in cost, easier to understand and do not suffer from complicated, expensive and troublesome power systems. You could fly for the next 20 years, have a fleet of planes and never need more than a two-channel radio. You can even enter national competitions and win championships with a simple, low cost two-channel radio and a two-*function* plane.

Two-channel gliders are excellent planes to use to learn to fly. I often recommend them.

Oh, you never thought of gliders? Maybe you should.

Two-channel - Rudder/throttle control or differential thrust - maybe

If one channel is used to control the electric motor, then *the other* can control *the flight path*. Usually these planes have been designed to climb on power and glide down on reduced power. Rudder is used to control direction. Planes, like the Firebird series are of this type. By placing the motor at the *correct* angle *for this type of plane*, the application of *enough* power will cause the plane to pitch up and climb. What this kind of plane cannot control is negative pitch. That is, you can't push the nose down to go into a directly controlled descent or dive. This limits your control in windy situations or where you need a more rapid descent than gravity and glide path provide.

My personal experience with these planes is that they fly well and are *relatively* easy *to fly,* but a new pilot cannot safely fly them in much wind. Since you can't dive into the wind, they are easily blown away with the pilot having little ability to fly the plane back up-wind. If you have one, fly it *only* in calm conditions.

An alternate design is the differential thrust models that have two motors. These planes have no flight control surfaces. Like the example above, when you apply full power they tend to climb and when you reduce throttle they glide down, but you can't direct the nose down to fight the wind. These planes steer left and right by changing the speed of the motors.

My personal experience with these is that they are even less wind worthy than the Rudder/Throttle planes. In dead calm conditions they can be fun, but control is so limited that I can't recommend them as trainers. But they can be a lot of laughs.

Thousands of new pilots have had their first taste of flying on these throttle/rudder or differential thrust planes. You can do some pretty cool things with them. However, without the ability to control downward pitch, to dive into the wind, these planes can be very easy to lose in any sort of wind, especially for the inexperienced pilot.

Three-Channel - Electric Power - Yes

We already achieved a yes for gliders with two channels. For un-powered silent flight, two is enough. In my opinion, when we have three *functions* to work with we have enough control for the new power pilot to have a good command of a plane with a motor. *The pilot* can control pitch, roll and speed. The plane can be managed *well,* but the controls are still quite simple. A plane designed around this channel count, can be a great learning platform and can carry the pilot long into the future.

In my opinion, the most important asset *gained* is the ability to push the nose down so that *the plane* can penetrate into the wind. If you have ever seen a glider pilot fly, you know that even though he does not have a motor, he has the ability to fly down wind and to come back against the wind. This is done through a controlled dive where the plane picks up speed so that its airspeed exceeds that of the oncoming wind and progress can be made over the ground.

Whether it is *rudder/elevator/throttle (RET)* or *ailerons/elevator/throttle (AET)*, this plane can be controlled *in all axes* and therefore gives the new pilot the authority to command the plane as he wishes. In fact, very exciting planes can be made with three-channel control. They can be highly aerobatic or they can be slow flyers that can fly indoors.

In my opinion, with three *functions* we have reached the minimum channel count for controlled powered flight. We have enough control, yet we can use very simple and inexpensive equipment to fly the plane. A radio *transmitter* with a single stick *and* slide, lever or switch *to control the motor speed* can provide all we need. I prefer proportional control of the motor, but even with only *an* on/off motor control you still have enough control. However, I always recommend proportional control for the motor.

For some, this will be all the control they will ever need. They can have slow flyers, high speed aerobats, beautiful scale ships and never lack positive control of the plane.

This is where I started my flight training and it has taken me quickly into all kinds of wonderful flying experiences.

Four or more *functions or* channels. - Yes Yes

If three is enough, why do we need more? The answer is *that* more *flying control functions or* channels give us more control. While we have positive control of a three-channel power plane, we can have *even* more positive control with four. Now we can have throttle, pitch, roll and yaw control and apply them all at the same time or *at* anytime of our choosing. This normally translates into throttle, rudder, elevator and ailerons. This can provide more controlled landings, or make 3D *aerobatic* flight possible. Aerobatics can be much more sophisticated.

While 2-channel beginner gliders are very common and three-channel beginner electrics are common, glow powered starter/*trainer* planes are much more likely to have four channels. Part of this is a matter of tradition and part has to do with the nature of the plane. Glow powered starter/*trainer* planes are typically larger, faster and more powerful than the typical starter/*trainer* electric *planes*. While the gliders might be larger, they are normally much lighter and travel at much slower speeds.

A typical glow powered starter plane might *weigh* 5 pounds *ready-to-fly* and *is* capable of 50 mph. It represents a lot more energy than a 3-channel, one pound electric*ally powered plane* that is moving along at 25 mph or a 30-ounce glider floating along at 10 mph. When you tell that bigger, faster plane to turn, you want to make sure you have as much control as possible.

For this reason, while I do not fly glow-powered planes, when speaking with potential new glow pilots, I normally recommend they equip themselves with a minimum of *the* four *flying functions*. There is no question that you can fly a glow-powered plane on *rudder, elevator and throttle,* but you won't find many around on the shelves of your local hobby store. Three-channel glow planes *are* more likely to be flying wings, *old-timers,* and *some* pylon racer designs. However these are not your customary *starter*/trainer planes in the glow world. *Old-Timers do make perfectly good RC 3-function trainers using glow, gas, old-time ignition engines or electric power*.

Five Plus - what are they for?

Let's just finish up with a brief overview of why you would ever have more than 4 *functions*:

Retractable landing gear - 1 channel
Flaps - one channel
Spoilers/airbrakes - 1 channel
tow release - 1 channel
Scale features -
Bomb doors
Powered canopy
and on and on
Show features -
Smoke
Glitter
Just imagine

Some functions can benefit from using more than one channel *on the receiver*.

It is *somewhat* common to put a servo on each aileron and assign them to individual channels. Now you can trim them from the radio and you can set up different *amounts of throw* up *and* down *for each aileron* to tune the plane for less drag. Using this setup you can also double duty the ailerons as flaps or spoilers.

Flaps are likewise often split between two channels for more flexible control.

Less common is the split elevator that has two servos on two channels that can be made to follow the ailerons to make the plane roll faster or perform other stunts more effectively.

It goes on and on. It takes expensive and sophisticated radio gear to handle some of these functions, but that cost is *coming* down and the ease of set-up is going up. Many beginners are now entering the hobby with computer radios as their first radio, or their first upgrade from an initial 2-, 3- or 4-channel standard radio.

SPACE

How much space do you *have to* have for flying?

If you have *a* totally clear space of at least 600' x 600', about 9 square acres, approximately 4-6 square football *or* soccer fields, then most Parkflyer class planes should be fine. These are planes that are typically two pounds or less and that typically fly at about 40 mph or less. These planes are commonly powered by Speed 400 or *Speed* 480 brushed motors. They also fly well at partial throttle. You can fly at less than full power and have more time to think and *be in* less *of a* rush to turn.

If your space is more like 200’ x 200’, one square acre or one football *or* soccer field, then a different plane is in order. Now you want something more akin to a Slow Flyer. These planes do very well at *less than* 20 mph and some can fly so slowly that you can almost jog with them. Their main challenge is their light wing loading and wing designs *that* make them challenging to fly in more than about 5 mph winds. However, for a new flyer with limited space, they make wonderful first planes.

These are my own designations and are based on my subjective ranking of the space a new flyer should have when learning on his own. An experienced flier can fly faster planes in smaller spaces. A new flier *needs* to have more space so *that* you are not in a constant state of panic trying to turn.

Of course you can get above the edges of the field and expand your space, but if you lose control, you *could* drop *into or behind* woods, on top of kids or smash someone's windshield. If that windshield is in a car that is traveling down a road when you hit the windshield, you could cause an accident or worse.

So much for space. You get the idea.

Summary

If you made it this far, you should get an award! By now you should have seen that there is no ideal best first plane. <u>It is a myth.</u> Many planes can be excellent first planes.

What we have discussed are the characteristics of planes that *are* better suited for new pilots.

Here is my mythical best first plane:
High-Wing
Significant dihedral
2- or 3-channel glider
3- or 4-channel electric
Foam construction - EPP, Elapor, EPO, Z-foam or EPS foam
I love gliders and feel they make great first planes/trainers
If it is *electrically* power, I think the pushers are outstanding

I hope you found some of this useful, helpful and perhaps interesting. If not, how did you get this far?

The AMA

The AMA, the Academy of Model Aeronautics, is an outstanding resource *for* the new and experienced flyer. I encourage you to become a member. *There* is an outstanding series of articles published by the AMA that will be really useful to new pilots. It is called, "From the Ground Up" by Bob Aberle. I highly recommend it.
http://www.modelaircraft.org/mag/FTGU/Part1/index.html

RC Clubs in the United States:
http://www.modelaircraft.org/clubsearch.aspx

International RC Clubs (*dead link*)
http://www.fai.org/fai_members/addresses.asp

RC Model Aircraft Quick-Start Guide by Bob Aberle is available from the AMA for FREE; call 765-287-1256 extension 212

Good luck new pilot and welcome to RC flying!

THE AMA PARK PILOT PROGRAM
http://www.modelaircraft.org/parkflyer.aspx

Since this e-book is focused on electric flight, I thought it would be appropriate to put something in about the AMA membership program developed specifically with electric pilots in mind. At half the price of *a* regular AMA membership, it seems to offer a nice package for pilots who are not interested in larger planes, glow planes, gas planes or jets. If you are primarily focused on small electrics, *small* electric helicopters or small gliders, this is something you should consider.

In addition, the AMA is looking to help form Park Pilot clubs and help those clubs establish Park Pilot fields. These clubs *are* focused on flying Parkflyers and *are* not open to gas, glow, jets or large *electrically powered* planes. As a result, they can be located in smaller fields and potentially in places where regular AMA fields have been rejected or cast out.

It certainly sounds interesting.

AMA Park Flyer Definition *and other AMA information about the Park Flyer Program*:

Park Flyer models will weigh two pounds or less and be incapable of reaching speeds greater than 60 mph. They must be electric or rubber powered, or of any similar quiet means of propulsion, including gliders. Models should be remotely controlled or flown with a control line, remain within the pilot's line of sight at all times, and always be flown safely by the operator.

Flying Site Development: (*bad link)*
http://www.modelaircraft.org/UserFil...iteBooklet.pdf

The AMA is encouraging the development of new, officially recognized AMA Park Pilot sites in metro areas throughout the US. As an aid in reaching this goal, we've developed a special "How to Start a Park Flying Site" turnkey package so members who are trying to secure a field won't have to start from scratch when they approach landowners or officials responsible for regulation of public facilities. The package includes a DVD to show landowners and park officials what park flying is all about—and how different it is from the engine-powered, radio-control flying with which they may already be familiar. There are tips on how to approach officials and landowners, plus instructions on how to set up a field. It even includes a guide for how to quickly and efficiently organize a club, its bylaws, and field rules. And best of all, members will be able to inform landowners and officials that they'd be covered by AMA site liability coverage in the amount of $2.5 million, which should serve as a great incentive. The goal is to make it easier for official AMA recognized flying sites to be developed quickly and in great numbers.

Rebates

http://www.modelaircraft.org/parkflyer/shops.aspx
Offset the cost of your new Park Pilot Membership! When you join you will receive rebate coupons in your membership package worth up to $50.00 Our partners include: Hobbico, Ready to Fly Fun, Hobby-Lobby, RC Micro World, and Rotory Modeler. Check out their web sites to see all the products they offer.

Click to join
https://www.modelaircraft.org/joinrenew.aspx

If traditional AMA clubs have turned you off, perhaps the best thing to do is to form your own club around the kind of flying that interests you, Parkflyers.

Things To Check On a Ready-To-Fly (RTF)

I think ready-to-fly *(RTF)* airplane packages are great. This is how I started flying. If I had been required to build a kit to begin my flying experience, I would never have gotten into the air. Now, after thousands of flights and years of flying, I have expanded to 20+ planes, multiple radios and all kinds of tools and things. I am having a ball. But there are things I know today that would have helped me with my first plane. Let me pass on some tips.

Regardless of the plane, RTF or not, <u>it is the pilot's responsibility to insure that the plane is flight ready</u>. If you put a plane in the air without checking it and without following the instructions, any problems that follow, any damage that *may be* caused is your fault and responsibility. It does not matter if the plane is defective, if you did not check it; any damage that occurred is your fault. I can't make it any clearer. No full-scale pilot would takeoff without checking everything. You should do the same.

READ THE INSTRUCTIONS!

There is a manual or instruction sheet that comes with your plane, read it! I read the manual several times on anything I get. It took the manufacturer time and money to create it. It contains important information. Some instruction sets are poorly done and some are very good. In either case, READ! If there is a video included, watch it. It was put there to help you. Take advantage of that help.

If the *manufacturer or supplier has* a Web site about the plane or product you purchased, visit the site. Sometimes there is a FAQ, frequently asked questions, page. Sometimes there are additions to the instructions that have been added since yours was packaged and shipped. And sometimes there are coupons, or specials for owners. Go, look and see, and benefit from the manufacturer's *or supplier's* Web site.

RTFM

I often post this in my notes on the forums, "RTFM". To put it politely, it means, " Read The Friendly Manual".

I have read many trouble reports by new flyers. They crash; they have problems and *they* are angry and upset. Why was this happening to them? Often, the answers were all in the instructions.

We had one club member who used to buy RTF planes, show up at the field and ask me how to get them set-up and flying. I would ask him for the instructions. "Oh, I left those home." I sent him home to get them. No matter how experienced I might be, unless I have this plane, I check the instructions.

He brought a computer radio to a meeting and asked me to show him how to use it. "Sure, where are the instructions?" He left them home. I could not help him, as I had never seen that radio before.

Needless to say, he crashed and crashed and destroyed things. Fortunately for him he had the money to do this. He occasionally created a safety situation and we had to "advise" him to change his ways. He has yet to become a successful flyer. He is still a nice guy and I hope someday he will be successful, but he needs to follow instructions.

THINGS TO NOTE WHEN YOU READ THE MANUAL

1) Does the plane need to be balanced, or does the balance need to be checked?

2) Are there linkages to be connected? Do they need to be adjusted? How do you adjust them?

3) Is there tape or glue to be added? Is there covering material to be removed?

4) Do the batteries need to be charged?

5) Do they recommend some kind of "break-in" procedure?

6) What is the proper range check procedure for the radio system?

7) What is the working range of your radio system?

8) How do you adjust the surfaces to get the plane to fly correctly? Are they moving in the correct direction?

9) What is the proper placement of the battery and how is it moved to adjust balance?

10) Is there a maximum recommended voltage that can be safely accepted by the ESC?

11) What wind speeds are recommended for new flyers?

12) How much space is recommended to fly this plane?

13) Who do you call if there is a problem? Do you call the hobby shop or the manufacturer? Is there a Web site?

14) Are there repair tips? What kind of glue can you use? Where can you get replacement parts?

15) What *radio frequency* is your plane using and how do you avoid channel conflict *with others*?

ASSEMBLY TIPS

Often, in order to meet a packaging goal or to keep the shipping weight down, the manufacturer will expect you to do something or to add something. These *tasks* are usually *completed using* common household items like tape or glue. In some cases the plane's balance has to be checked and/or adjusted. The *manufacturer* may include weights, or you may need to buy weights, but coins work too. A dime is about 0.1 ounces and a quarter is about 0.2 ounces. Coins can actually be cheaper than buying weights.

It is common to have to mount the tail and the wing. Are there alignment marks or procedures that you are to follow? Do you have to remove covering material so the glue will hold properly? *What type of glue should you use?* How many rubber bands are needed to hold the wing *on* properly? Don't use less than the recommended number of rubber bands.

My Great Planes Spirit 2M glider came RTF, including the radio system. This was my second plane after my Aerobird. The Aerobird did not need to be balanced, the Spirit did. If I had tried to fly it without balancing it first, I would likely have broken it badly on the first flight. It took four ounces of weight in the nose to get *it* to balance properly.

A friend's RTF was brought to the field so *that* we could help him. Following the instructions we did a range check and found *that* there was a problem with the radio system. No problem! He packed it up, took it to the hobby shop and they exchanged it immediately. He was back at the field in an hour. It was clear *that* it had not been flown, so there was no question of flight damage. If he had flown and crashed it, they could have easily refused to replace it, and they would have been right, as crash damage is not covered under warranty. It was the pilot's job to make sure the plane was flight ready.

FLYING TIPS

Often RTFs come with flight instructions and tips. One of the most important *tips* to follow is related to wind. Many planes, especially two-channel planes, do not handle wind very well, especially in the hands of an inexperienced pilot. If you don't know this, you could loose your plane, or worse, you could hit someone or cause damage. What wind speeds are recommended, especially for new pilots?

Sometimes the plane will "porpoise" or tend to roll, or want to dive. Is it you or is it the plane? The instructions may tell you.

Once the pilot has become comfortable with the plane, there may be adjustments that can be made to make the plane more responsive. Sometimes it is *a* switch on the radio, or a button *that* you need to push that goes from mild to wild. Or maybe you have to turn something on the linkage, or move the linkage to a different hole. Go back and read the manual for the proper procedures to make those adjustments.

SUMMARY

Just because the plane says ready to fly, don't take that literally. Compared to a box of sticks and a tube of glue, it is ready to fly. However there are often set-up procedures, or assembly steps that need to be done. It is best to read the instructions to see how to do them correctly. You will have a much better flying experience and your plane will last longer.

What You Need To Know About Receivers

Revised February 2008

You control the plane by moving controls on the radio *transmitter*, but it is the *radio* receiver that "hears" the radio *transmitter* and directs those commands to the proper servos to move them according to your wishes. What do you need to know about receivers when preparing and flying your plane?

By convention all radio systems use a transmitter and a receiver. *Technically, the 2.4GHz systems consist of two transceivers, a transmitter and receiver combined in one unit.* However in common use, in the RC airplane hobby, *some people* typically refer to the transmitter*, the unit held by the pilot,* as the radio. While this is technically incorrect, everyone knows what we mean, so I will speak of the radio and the receiver. For those of you who are radio systems wizards, I hope you will forgive me for this convenience.

FREQUENCY AND CHANNEL

Receivers are specific to a given frequency. For example, in North America, NA, our planes can be flown on 27 MHz, 72 MHz, and now 2.4 GHz. There are others, which *are legal* too. Your receiver has to match the frequency of your radio *transmitter* in order to be able to hear it. In NA 72MHz is considered the RC aircraft hobby *frequency band and* it is split into 50 sub frequencies, or *what we call* channels so that we can have more than one person flying a plane at any given time. In NA, 27MHz is typically only seen in low-end RTF planes and is shared with low-end cars and boats and is limited to 6 *specific frequencies within the 27Mhz band*.

In the last few years, 2.4GHz has come on the scene and is growing fast. The main attraction *of* 2.4GHz *radio systems* is *that* there is no need for frequency control, which we will discuss later. Also, this system operates well above the frequency level of most of the *radio frequency* "noise" that is generated by other components in the airplane. The 2.4GHz systems are less likely to pick this up as interference. However because of the very short wavelength, they *are* more prone to having the signal blocked. There will be more on this later.

With non-2.4GHz systems your receiver needs a crystal that matches the channel *frequency* of your radio *transmitter*. In RTF packages, this is already done, so you don't need to worry about it. However, if you are buying your own receivers *that require a crystal*, you must match them to the frequency and channel of your radio *transmitter* when you buy them. Your supplier can help you with the details. One suggestion is that you not mix crystal brands. They may work, but this introduces a risk that you are better off avoiding. If you get a Hitec receiver, get a Hitec crystal. *The crystal also has to match the receiver's conversion form. For example, a single conversion Hitec receiver not only requires that the crystal match the frequency of the transmitter, but the crystal also needs to be for use with a single conversion Hitec receiver.*

AM and FM and FM SHIFT

Just like your car radio, RC radios can use AM or FM to transmit their instructions to the plane. AM is an older technology but it is still in use, primarily in low-end 2- and 3-channel radios. However most new radios are FM. Both *types* work!

In North America, 72MHz systems are grouped by those using positive shift and those that use negative shift. Typically we speak of JR and Airtronics as positive shift. Hitec and Futaba are negative shift. In some cases *the transmitters of* these brands can be made to change shift through a function called shift select or reverse shift that can be set at the radio *transmitter*.

Shift refers to how the radio codes instructions for the receiver. One is not better than the other. They are just different. This is only important when you are buying a new receiver, as you need to be sure that your FM receiver and your FM *transmitter* are using the same shift.

Crystals are not specific to shift, but they may be specific to AM vs. FM. Be sure you get the right type of crystal for your receiver.

FM/PPM and FM/PCM

PPM and PCM further define how the radio codes commands to the receiver. We normally speak of PPM and PCM in the context of FM radio/receiver combinations. If you are buying an AM receiver/radio, or a 2.4 GHz system you don't need to take this into consideration.

FM receivers can be either PPM or PCM. When people say FM, they typically mean FM/PPM. If they say PCM, they mean FM/PCM.

As long as the shift is right, you can mix brands of FM/PPM radios and FM/PPM receivers. On the other hand, FM/PCM receivers are highly brand specific. If you have a Futaba radio capable of PCM transmission and you wish to use a PCM receiver, you must have a Futaba PCM receiver that is compatible with that model radio. No mixing brands in PCM.

As far as I know, all FM radios can transmit in FM/PPM. Some can transmit in FM/PCM also. I don't know of any that are FM/PCM only, but there may be one out there. If PCM is listed, it is normally an extra feature, not a requirement *that* you use *the* PCM *function*.

Some will say that PCM is better and more reliable. I can neither confirm nor dispute this point, as I have not done testing. I use both and have found both reliable. I will point you to a couple of articles that discuss PCM, how it works and their opinion of the advantages.

Futaba FAQ on Advantages of FM/PCM over FM/PPM
http://www.futabarc.com/faq/product-faq.html#q102

Article on PCM vs. PPM
http://www.aerodesign.de/peter/2000/PCM/PCM_PPM_eng.html#Anker143602

PCM receivers tend to be more expensive, larger and heavier. From what I gather, FM/PPM is what the overwhelming majority of fliers use. FM/PCM seems to be most popular in the high performance world, giant scale and competition planes. Choose whichever you like, as either will fly your plane.

RANGE

For practical purposes, the receiver, not the radio *transmitter*, determines range. It is a function of *the* sensitivity of the receiver and its ability to pick out the radio signal and filter out *radio frequency* noise. Many brands state the rated range of their receivers and some do not. I suggest you stick with brands that state their rated range or at lest advise of their intended purpose. Otherwise you could end up flying beyond the range of your receiver.

How much range is enough? That depends on the application. You can NEVER have too much range, but you can have too little. If the plane gets out of range it will crash or fly away. More range is always better.

Here are my suggestions for minimums:

Indoors

Indoor planes are usually very weight sensitive, every gram counts. To get *a receiver with* extremely light weight, sometimes range has to be sacrificed, but that is OK indoors as long as you know what *the range* is. I suggest 200' minimum and more is better, but you may be fine with less. Many indoor flying spaces are less than 100 feet along any span and you are not going to accidentally fly past the walls.

Outdoor - Planes

Slow Flyers, micro helicopters and small electric planes *with* wingspans under 36" can often get by with ultra light receivers with ranges of as little as 500 feet. This is adequate if you have a small model or fly in a small field of under 500 feet in span. Many of these small models can be hard to see at ranges of more than 300 feet, approximately the length of a*n American* football field. I prefer more range, but many people do fine with 500-foot receivers. The GWS pico 4-channel is a good example of this kind of receiver.

Today there are plenty of micro receivers with 1000' or greater rated range that are *less than* 1/3 ounce, about 9 grams. I have a large field that is 1600 feet long. It is easy for me to get a plane out beyond 500 feet without realizing it. While it can become hard to see *it* at that range, I don't want to lose it because I ran out of receiver range.

If you can tolerate up to *a* 1/2 ounce, about 14 grams, for your receiver, then there is no reason to use a receiver with a 500-foot range limit, except *for the* price. The Spektrum DX6 *2.4Ghz* receivers are good examples. *They are* tiny in size. They are safe *and have a* working range of 1500 to 2000 feet. The Hitec Micro 05S at 0.3 oz, about 8 grams, has a range of 1 mile. *The* Berg*, by Castle Creations,* and others make tiny receivers with over 1500' range ratings. Why limit yourself with short-range receivers and take a chance of losing you model?

For 2M gliders, sailplanes, fast electrics or glow planes with wingspans of 2 meters, about 80 inches or less, I recommend a minimum of 2600 feet, 1/2 mile or 1 KM depending on how your receiver specs are given. More is ALWAYS better.

For planes with *wingspans* greater than 2 Meters or 80 inches, and especially thermal duration sailplanes, I recommend *that* you use a receiver with a 1 mile, 1.5 KM or 5000 foot + rating. It is quite easy to get these planes out 3/4 of a mile, especially the larger sailplanes, and you don't want to have signal problems with a plane this large that is out that far. This will give you good signal strength for the likely distance you will fly the plane, which is probably no more than 75% of that range.

If your receiver is rated for "line of sight" that means that as long as you can see the model *and are aware of its orientation*, you should be able to control it. These receivers will be your longest-range receivers.

SIGNAL PROCESSING - Single and Dual Conversion, DSP and more

In addition to range, 72MHz FM receivers will usually specify if they are single conversion, dual conversion, or that they use some other method of signal processing. I will leave it to the engineers to go into depth here. However, as a general rule, dual conversion is better than single *conversion*, but there are excellent single conversion receivers that have digital signal processing *(DSP)* and other ways of making sure they pick up the right signal.

I have no hesitation to use single conversion receivers with 2600 foot, (1KM or .6 mile) rated ranges in my models that will be flown less than 1500 feet out. Most of my electric planes can't be easily flown further than that. Since I am operating at less than 70% the rated range, I feel comfortable that good quality single conversion receivers should be fine. This includes my 2M sailplanes.

For my larger sailplanes I use only dual conversion *FM* receivers. Here I am flying planes that may be over 1/2 mile out and 1000 feet or more in altitude. I need every bit of signal processing I can get to insure I get clean control. I can't afford even a single glitch. If my plane is on 72MHz I want a dual conversion system.

You make decisions based on your type of flying. This is what I do.

Some receiver brands offer single conversion, dual conversion and perhaps other types of receivers. Be sure you get the right kind of crystal based on the receiver. For example, Hitec dual conversion receivers and single conversion receivers *require* different types of crystals. I don't know what makes them different, but you cannot interchange them. They won't work.

CHANNELS *or Functions*

We spoke of channels above in terms of frequency. We also use the word channels to describe how many servos/devices/*functions* you can control. A 4-channel radio can control up to 4 devices. It is OK to have more channels in the receiver than your radio *transmitter* has, as some slots are used for things other than *flight function* control. For example, if we have a 4-channel radio and are flying a 4-channel plane your slots might be used like this:

1 *slot* per *flying* control function = 4
1 *slot* receiver battery
1 *slot* for plane locator or battery monitor

In this case you might want a 6-channel receiver to give you 6 slots, or you can use one or more “Y” cables to share slots. However, I prefer to have a receiver with extra slots rather than use “Y” cables. I feel it will give me greater reliability. Rather than putting money into “Y” cables I would rather put the money into the receiver.

If you have a 3-*function* electric plane, you need a minimum of a 3-channel receiver. You don't typically need a separate slot for a receiver battery as your electronic speed control *can* provide the receiver with battery power from your motor battery. You can use a 3-, 4-, 5-, X-channel receiver, but it must have at least 3 channels.

You can also use a 2- or 3-channel receiver with a 4 or more channel radio *transmitter*, but you will only have 2 or 3 channels of control available. An example might be to use a 3-channel receiver for your *rudder, elevator and throttle,* R/E/T, plane but use a 4-channel radio *transmitter* to fly it. That works!

COMPUTER RADIO AND CHANNEL MIXES

True for all radios regardless of frequency

If you are splitting functions *by* using mixes in a computer radio your receiver may need more channels. For example, if you have a computer radio, you might be able to use two servos for your ailerons and have each work from its own channel *function slot*. Each aileron will be controlled by its own channel. Some radios can put the second aileron on any channel *slot* and some require they be on specific channels. Consult your manual for guidance here.

Here is an example where we use more than one slot for a function because we have individual servos on each surface. This is the layout of one of my gliders and is controlled from my Futaba 9C computer radio. I use an 8-channel receiver and 7 servos.

Ailerons - channels 1 & 7
Flaps - channels 5 & 6
Elevator - channel 2
Rudder - channel 4
Tow hook release Channel 8
Battery - uses *the* channel 3 slot
Plane Locator - Shares *the* channel 8 slot with the tow hook release servo via a “Y” cable

POWER TO THE RECEIVER

Most receivers *are designed to* operate at 4.8- to 6 volts. This is usually supplied by a 4- or 5-cell NiCd or NiMH receiver pack. In planes using glow or gas power, or in gliders, this is a battery pack that plugs into the receiver or into a switch *harness* that goes into the receiver. There are some new receivers that can work on a two-cell lithium polymer pack of 7.4V, but these are rare. There are some tiny receivers, made for indoor flight, that can operate *using* one Li-Poly cell at 3.7V, but these are also rare. Always read your manual, but in general, never directly plug a battery pack of more than 5 *NiCd or NiMH* cells, or 6 volts, into your receiver or you will release the "magic smoke" and the receiver will not work. You could fry the servos too, so RTFM, read the friendly manual.

If *the* plane has an electric motor, the receiver *may* get its power from the *battery eliminator circuit, BEC, which is a part of the* ESC, electronic speed control. Note that even though your flight battery might be 7.2V or higher, the *BEC part of the* ESC has a circuit that steps the *higher input voltage* down to 5 volts to power the receiver *and servos*. This circuit, called the BEC, battery eliminator circuit, eliminates the need for a separate receiver battery.

If you look at the manual for your ESC, it probably indicates that, if you use more than a certain voltage *(number of a certain kind of cells)* for your motor pack, you will need to go to a separate receiver battery *or a separate switch mode BEC*. This is because the *commonly used linear* BEC can only step the voltage down so far. Or it may say the BEC can handle up to 4 servos on the receiver *when using* a 9.6V motor battery, for example, but you are restricted to 3 servos if you go above that. *For more servos than* that, *the BEC* has to be bypassed. You need a separate receiver pack *or separate switch mode BEC*.

There is an article on the BEC in this e-book. Be sure to read it.

Summary

The receiver is the most critical of all the electronics you will put in your plane. The most expensive radio *transmitter* with the wildest features is just a paperweight without a good receiver to carry out its instructions. While the terms can be confusing at first, you should now be prepared to choose a receiver with confidence. Remember to always consult your radio manual for any specific needs of your radio system.

A key point is that it is the receiver, and not the radio *transmitter*, that really dictates the range you can expect. I encourage you to be very aware of the range rating of your receivers so *that* you don't lose a plane by exceeding your safe range.

Your receiver has to have enough channels *or functions* to accept commands from your radio *transmitter* and to accommodate the number of servos *and other* devices you have in the plane. However the number of channels in the receiver does not have to match the number in your radio.

Your receiver needs to match your radio in the areas of shift and frequency as well as FM/PPM or FM/PCM features. For FM/PPM you can mix and match receiver brands, *being sure the shift is correct,* but with FM/PCM you can't!

New generations of radio systems are now coming into wide use. These are based on 2.4GHz and do away with many of the issues and points of consideration discussed above. Here are a few links that may be of interest to allow you to get to know this technology. I have been encouraging all new pilots to go this way. 2.4GHz is here, it is now, and it appears to be the wave of the future.

http://www.rcgroups.com/forums/showthread.php?t=715589&goto=newpost

2.4 GHz - A Broad Market Review
http://www.wattflyer.com/forums/showthread.php?t=22170

Good general article on radios by the Torrey Pines Gulls Web Site. (*dead link*)
http://www.torreypinesgulls.org/Radios.htm

What *Function* Goes on Which Stick?

If you are flying a RTF electric plane, your radio and servos are already set-up for you. However, if you are setting up an ARF*, almost ready to fly,* or finishing a kit, you will be installing your own radio equipment. Which stuff goes on which stick, and why?

We usually talk about what surface is controlled by what stick. However, that is not really the right way to look at it.

First, the control axes:

Pitch - nose up/nose down - usually controlled by the elevator or elevator function of elevons *(combined elevator and aileron surfaces)*

Roll - rotation of the wings around the fuselage - controlled by ailerons or the aileron function of elevons.

If the plane does not have ailerons or elevons, then *the* roll can be controlled by the rudder or the rudder function of V-tail ruddervators, depending on the design of the plane. On rudder only planes, the rudder works with dihedral (the upward slant of the wings) in the wings to roll the plane.

Yaw - movement of the nose left or right - controlled by rudder or the rudder function if V-tail ruddervators *are used.*

Speed - throttle control

If you are in a different part of the world, you may be flying Mode 1, 3 or 4. I live in North America where Mode 2 is the standard, so the rest of this post will be referencing Mode 2 control positions.

Note that I mention Mode 2, which is marked with the * below.

Left stick	Right Stick	Mode
Pitch and Yaw	Speed and Roll	1
Speed and Yaw*	Pitch and Roll*	2*
Pitch and Roll	Speed and Yaw	3
Speed and Roll	Pitch and Yaw	4

For a power plane, landing gear, flaps and other such functions are assigned to switches, buttons, dials, sliders or levers, but are not defined as part of the Mode definitions.

For a two-stick radio, used in Mode 2 format, the standard format in North America, pitch and roll are on the right stick with roll ALWAYS being your primary turning control. Yaw and speed control are on the left stick.

Based on Mode 2, it is very easy to move from a dual-stick to a radio *transmitter with a* single stick as the right, or the only stick, always has your primary fight controls of pitch and roll.

Primary Speed control

Since this is written for electric flyers, we will assume you have an electric motor. On a two-stick radio, the speed control is on the left stick and is controlled by the motion that goes toward you to turn the motor off and away from you to give full throttle. For a radio *transmitter with a* single stick the throttle control is usually on the left side *or back of the left side of the transmitter* and will be a slide, switch or lever.

What stick movements control the pitch?
By Ken Myers, May 2009

I've found that some folks don't understand which way the elevator stick is supposed to move the elevator, so I've added this section here.

With Mode 2, when the right stick is pushed forward, away from the pilot holding the transmitter, the elevator goes down on the plane which lifts the tail of a flying plane up and forces the nose of the flying plane down. If the right stick is pulled towards the pilot, the elevator surface on the plane moves up, pushing the rear of the flying plane down and the flying plane's nose pitches up.

Where does the rudder control go?

Confusion often exists around where to put the rudder control. Depending on the design of your plane, the rudder can play different roles, so its placement can change. On a three-channel electric plane without ailerons, the rudder is your primary turning surface. It provides both roll and yaw control so it goes on the right stick for roll control, as the primary turning surface. This stick also has pitch control provided by the elevator. The rudder will work with a feature of the wings, called dihedral or polyhedral, to roll or bank the plane when you want to turn.

What if there are ailerons, or elevons *(combined elevator and aileron control)*?

Primary flight controls of pitch and roll are always on the right stick, or the only stick. If this is a 3-channel plane with throttle, aileron and elevator controls only, like a flying wing that has elevon controls (combined elevator aileron in one surface), now where do I put things? Think of function rather than surface and you will know immediately. Which surface provides roll control? In this case it is the ailerons, so they go on the right stick with the elevator, which provides pitch control.

If this is a 4-channel plane that has ailerons and a rudder, the ailerons are your primary roll control, so they go on the right stick. The rudder moves to the left hand stick to provide yaw control, which helps the ailerons turn the plane smoothly.

If you are flying off a runway, the rudder can be very valuable as it helps control your path down the runway during take-off and landing. If you have a steerable ground wheel it is usually attached to the rudder or the rudder channel. The rudder, in this configuration, also plays a valuable part during landing when we may wish to redirect the nose of the plane without tipping the wings using the ailerons.

Moving from *a radio with a* single stick to dual-stick radios

Some people feel *that* it is confusing to move from a radio *transmitter with a* single stick to a dual stick radio, however, if you are flying Mode 2, it really isn't confusing at all. If you think of your radio and your controls in this manner, there is no confusion moving back and forth between *a transmitter with a* single stick and dual-stick radios or between three channel R/E/T planes and A/E/T planes or planes that are A/E/R/T.

On a radio *transmitter with a* single stick, pitch and roll are on the single stick, which happens to be oriented to the right side of the radio. If this is a dual-stick radio, pitch and roll are still on the right hand stick. It doesn't matter if it is a rudder *and* elevator plane or an aileron *and* elevator plane. Pitch and roll are on the right stick, or the only stick.

Think of your controls this way and there is never a doubt what goes where or which controls to use when you switch between radios and planes.

Battery Basics

Revised January 2007

All RC planes use battery packs to operate their electronics. On planes that don't have electric motors we call these *batteries* receiver packs, as they power the receiver and the receiver then distributes the power to the servos and other electronics in the plane. However, for electric planes, we also use batteries to power the motor. They are the chemical fuel tanks and fuel pumps that store and deliver the energy we use to fly.

Battery packs are made up of cells, which act as a chemical storehouse for electrical energy. When multiple cells are joined together we call this a battery or battery pack. There are a variety of battery types. Each has advantages and disadvantages that we will discuss.

Battery Types

At the time of this writing, there are *four* commonly used rechargeable types of cells. They vary by the chemical mix that is used to hold and deliver the electricity.

Nickel Cadmium, NiCd, have been around the longest.

Nickel Metal Hydride, NiMH came into use later and are popular today *in small electric models and as receiver and transmitter packs.*

Lithium cells are typically lithium polymer, Li-Poly, and the less commonly used Lithium Ion and Lithium Iron Phosphate. These are the newest breeds of chemical cells.

NiCd packs have the lowest power to weight ratio. That is to say that for a given electrical capacity they will weigh the most of the three types. However they have the ability to be charged faster than *NiMH or Li-Poly, but not Lithium Iron*

Phosphate, and will give up their power fast. *Which means that they can be discharged at relatively high currents.* While still in common use, they are dropping in popularity as the other types are improving and gaining on NiCds advantage of quick charge and quick discharge. Each NiCd cell is rated at *a nominal* 1.2 volts.

Nickel Metal Hydride, NiMH, packs hold about 40% - 60% more capacity per ounce than NiCds. For example, an 800mAh NiCd pack might weigh 6 ounces while an equivalent capacity NiMH pack might be 4 ounces. Except for very high performance, NiMH packs can't quite match NiCds for how fast they can deliver their electricity or how fast we can charge them, but they are catching up. There used to be a big gap, but the gap is closing fast. NiMH is far more popular today then they were just a few years ago, and probably have passed NiCd in usage. Each NiMH cell is rated at *a nominal* 1.2 volts, the same as NiCd cells.

In many ways NiCd and NiMH cells are very similar in their application. As shorthand, I am going to start to refer to NiMH and NiCd as NiXX when what I am saying applies to both. I hope this does not lead to confusion on the reader's part.

Lithium *polymer* packs are the lightest for their capacity. They typically hold 4 or more times as much electricity per ounce when compared to NiCd packs. For example a 6-cell, 7.2V 2100mAh NiCd pack might weigh 12 ounces while a 2-cell 7.4V Lithium *polymer* pack, of the same capacity, will be *a little over* 4 ounces.

Because much of our RC electronics have been based on 4- and 5-cell NiXX packs they are tuned for 4.8-6V receiver packs. However Lithium *polymer* packs are *a nominal* 3.7V *per cell,* so one cell is a bit low and two cells, at 7.4V, is a bit high. Lithiums *polymer batteries* have not been in common use for receiver packs used in gliders or glow powered planes. Some micro plane electronics systems have been designed for 1-cell lithium *polymer* packs and the newer generation of electronics, for the rest of the market, are being retuned to accept 1-2 cell Li-Poly receiver packs.

As a result, Lithiums *polymer batteries* have been used primarily as motor *power* packs. Up until recently, Lithium *polymer* packs have been slower to charge and slower to deliver their power. The newest generation Li-Polys can now deliver high currents but still need to be charged at 1/3 the rate of NiCd or 1/2 the rate of NiMH motor packs. However, over time, they are improving. They are growing in popularity as the charge/discharge rates improve and the prices come down. Each Lithium *polymer* cell is rated at *a nominal* 3.7 volts.

Pack Configuration

Unless stated otherwise, we join the cells into packs by joining *the individual cells* in series. In series we add the voltage of each cell so that a 6-cell NiXX pack will be rated at 6 times *a nominal* 1.2 volts or 7.2 volts. With lithium *polymer* packs, which are rated at *a nominal* 3.7 volts per cell, it would take two cells to create a comparable 7.4 volt pack. When you hear people talk about 4-cell, 6-cell, or however many cells today, they are usually talking about NiCd or NiMH cells. However, with the rise of Lithiums *polymer cells*, you should ask to be certain that they are not talking about lithium *polymer* cells.

Clearly if your instructions say that your motor can use a 7-cell pack, it would be important to know if that is 7 NiXX cells or 7 Lithium *polymer* cells as the voltages would be very different. A 7-cell NiMH or NiCd pack would be 8.4 volts. A 7-cell Lithium *polymer* pack would be 25.9 volts.

While it is unusual to combine NiCd or NIMH packs in parallel to increase capacity, it is quite common with Lithium *Polymer* packs. This has spawned the xSyP designation, were x is how many Lithium *Polymer* cells are connected in series and y is how many groups of these cells are connected in parallel. A3S2P pack would have two groups of 3 cells. This allows us to deliver higher amperages at the same voltage, or to provide more capacity for longer flights at the same voltage. The xSxP designation is most commonly used with Lithium *Polymer* packs. I don't recall ever seeing this used with NiXX packs.

Battery Chargers

When charging your battery packs you MUST use the right kind of charger or you will damage the cells. Using the wrong charger, especially with lithium *polymer* cells, can actually lead to a fire or an explosion. Be sure that you have the right charger for the kind of cells you are charging. Some chargers are specific to one kind of cell while some can charge two kinds and some can charge all *cell chemistries in use today*. Make CERTAIN you know before you charge or you could put your model, your car, your home or your personal safety at risk.

I hope this has been helpful. Below are some additional resources for further reading.

Excellent overview and safety information on Lithium *Polymer* Batteries
http://www.rchobbies.org/lithium_battery_breakthrough.htm
http://www.rcgroups.com/forums/showthread.php?t=209187

Lithium *Polymer* Battery Balancers and Chargers
http://www.rcgroups.com/forums/showthread.php?t=599287

More on Batteries
http://www.modelaircraft.org/mag/FTGU/Part8/index.html

A123 CELLS – (*Lithium Iron Phosphate cells produced by A123 Systems, Inc*.) This is an emerging cell for electric plane use.
http://www.rcgroups.com/forums/showthread.php?t=618071#post6636651
http://homepage.mac.com/kmyersefo/M1-outrunners/M1-outrunners.htm

The Battery Clinic
http://www.rcbatteryclinic.com/

Amps Versus Volts Versus C

Edited by Ed on 2/19/2008

This brief discussion is intended to clear up a few terms and concepts around electricity as it applies to electric airplanes.

Think of electricity like water. Volts = pressure
Amps = flow

Volts are like pounds per square inch, PSI. That says nothing about how much water is flowing, just how hard it is being pushed. You can have 100 PSI with zero water flow.

Amps are the flow, like gallons per hour. You can have flow at low pressure and you can have flow at high pressure.

Amp hours (Ah) are how much flow can be sustained for how long. It is used as a way of *stating* how much *electrical energy* is *contained* in the battery. *That is its capacity*. It is like how many gallons of gas *are in a full gas* tank. *Different vehicles have different size gas tanks*. It is a capacity number. Ah says nothing about the flow or pressure. It is *all* about the capacity.

What is the relationship of amps *to* milliamps? We are just moving the decimal point around.

1 amp (short for ampere) = 1000 milliamps (milli means 1/1000)

Examples

A 7-cell NiMH or NiCd pack provides 8.4V (pressure).

The motor will draw electricity from the pack at a certain flow rate, or amps.

If you have a have a 650-milliamp hour *(mAh)* pack, it can deliver a flow of 0.650 amps (650 milliamps) for one hour. If you draw *the stored energy* out faster, it doesn't last as long. *If a constant 6.5 amp load is placed on the pack, the stored energy is depleted 10 times faster than the 0.650 amp load. The hour stated as 60 minutes, is then divided by the 10 times higher load and the pack is emptied in 6 minutes*.

An 1100mAh pack has *about* double the capacity of the 650mAh pack, so it should last "about" twice as long with the same draw *on it* as a 650mAh pack.

What is C in relation*ship* to the *battery's recommended maximum charge current*?

C ratings are simply a way of talking about charge and discharge **rates** for batteries.

1C = 1 times the rated *Ah* capacity of the battery. If you charge your *0.65Ah (*650mAh*)*, pack at 1C, you charge it at *1 times 0.650Ah or 0.650 amps, which is* 650 milliamps.

1C on a *1.1Ah (*1100mAh*)* pack would be *1 times 1.1Ah or* 1.1 amps.

2C on your *1.1Ah (*1100mAh*)* pack would be *2 times 1.1Ah or* 2.2 amps

Motor batteries are often rated in Discharge C and Charge C.

An 1100mAh pack (1.1 amp hour) might be rated *by a manufacturer or supplier* for *a* 10C discharge *rate*. You can pull *10 times 1.1Ah or* 11 amps (flow) without damaging the battery.

Then it might be rated at *a* 2C charge rate (flow), so you charge it at *2 times 1.1Ah or* 2.2 amps (2200mAh)

How did I do? Are things clearing up?

If you have a *0.5Ah* (500mAh*)* pack - any kind - and it is rated at *a* 16C *discharge rate,* that means it can deliver *safely up to* 8 amps*, which is 16 times 0.5Ah.*

If you have a *1.0Ah (*1000mAh*)* pack - any kind - and it is rated at *an* 8C *discharge rate,* that means it can deliver *safely up to* 8 amps*, which is 8 times 1.0Ah.*

If you have a *1.0Ah (*1000mah*)* pack - any kind - and it is rated at *a* 12C *discharge rate* that means it can deliver *safely up to* 12 amps, which is 12 times 1.0Ah.

If you have a *1.5Ah (*1500mAh*)* pack - any kind - and it is rated at *an* 8C *discharge rate that* means it can deliver *safely up to* 12 amps, *which is 8 times 1.5Ah.*

If you have a *1.5Ah (*1500mAh*)* pack - any kind - and it is rated at *a* 20C *discharge rate* that means it can deliver *safely up to* 30 amps*, which is 20 times 1.5Ah.*

If you have a *3.0Ah (*3000mAh*)* pack - any kind - and it is rated at *a* 10C *discharge rate* that means it can deliver *safely up to* 30 amps*, which is 10 times 3.0Ah.*

If you need 12 amps, you can use a pack with a higher C rating or a pack with a higher *Ah*/mAh rating to get to needed amp delivery level.

The C Rate and Its Relationship to Time
By Ken Myers May 2009

The recommended C rate for charging and discharging a battery has a direct relationship to the minimum amount of time it will take to safely charge a completely empty battery or to safely discharge a completely full battery.

If a battery has a maximum charge rate recommendation of 1C, it will take about 1 hour to charge the battery if it was completely empty. It doesn't make any difference what capacity the battery has. If the charger is capable of charging at a 1C rate, it will take one hour.

Example 1: 2.1Ah (2100mAh) battery at 1C rate
From the previous examples it can be seen that the maximum charge current at 1C is 2.1 amps. 2.1 amps for a period of one hour is 2.1 amps per hour or 2.1Ah (2100mAh).

Example 2: 4.2Ah (4200mAh) battery at 1C rate
The maximum charge current is 4.2 amps for a period of one hour, which is 4.2 amps per hour or 4.2Ah (4200mAh).

Remember, these numbers are for a completely empty battery.

Some types of batteries can be charged at a higher rate. Always be sure to check the manufacturer's recommendations!

The new Hyperion G3 Li-Poly batteries, as well as some other third generation Li-Poly batteries, have a 5C charge rating. How does this equate to time?

Example 1: 2.1Ah (2100mAh) battery at a 5C rate
From the previous examples it can be seen that the maximum charge current at 5C would be 5 times 2.1 or 10.5 amps. 10.5 amps for one hour would be 10.5 amp hours (Ah). 2.1Ah is 1/5 of 10.5. 1/5 of an hour is 12 minutes to fill the empty pack. 5C is always 12 minutes.

Example 2: 4.2Ah (4200mAh) battery at 5C rate.
The maximum charge current is 5 times 4.2 or 21 amps. 21 amps for an hour would be 21Ah, which is 5 times greater than the 4.2Ah rated pack. It takes 1/5 as long to fill an empty pack, or again 12 minutes. 5C is always twelve minutes.

Good luck on finding any Li-Poly chargers that can do a 5C charge on 2.1Ah capacity cells and greater!

Remember, when charging, you can always use less current than the recommended maximum. The charge will just take longer. You should not use a charge current above the recommended maximum.

The discharge current's maximum is also recommended with its C rating. The C rating is the maximum, and a battery doesn't have to be used at the maximum, anything less is fine, and most likely better.

Example 1: 2.1Ah (2100mAh) with a 10C discharge rate
10 times 2.1 = 21 amps as the maximum. 21 amps for one hour is 21Ah, but the pack has a capacity of 1/10 that. 1/10 of an hour is 6 minutes. If the 21-amp draw remains constant, the battery is depleted in 6 minutes.

Example 2: 2.1Ah (2100mAh) with a 25C discharge rate
25 times 2.1 = 52.5 amps as the maximum. 52.5 amps for one hour is 52.5Ah, but the pack has a capacity of 1/25 that. 1/25 of an hour is 2.4 minutes. If the 52.5-amp draw remains constant, the battery is depleted in 2.4 minutes.

Yes, the time is exactly the same for larger capacity packs.

Example: 4.2Ah (4200mAh) with a 25C discharge rate
25 times 4.2 = 105 amps as the maximum. 105 amps for one hour is 105Ah, but the pack has a capacity of 1/25 that. 1/25 of an hour is 2.4 minutes. If the 105-amp draw remains constant, the battery is depleted in 2.4 minutes.

Here are some numbers you need to relate C and time
1C = 1 hour (60 minutes)
2C = 1/2 hour (30 minutes)
5C = 1/5 hour (12 minutes)
10C = 1/10 hour (6 minutes)
15C = 1/15 hour (4 minutes)
20C = 1/20 hour (3 minutes)
25C = 1/25 hour (2.4 minutes – 144 seconds)
30C = 1/30 hour (2 minutes)
40C = 1/40 hour (1.5 minutes – 90 seconds)
45C = 1/45 hour (1.3 minutes – 80 seconds)

Manufacturers are supposed to derive the capacity of their cells using a 1C discharge rate. They generally round up. The number that appears neatly printed on the label or in the specifications sheet for a given cell was supposedly done at a 1C rate. The usable capacity actually decreases as the C rate increases.

The "safe, usable capacity" of Li-Poly batteries is about 80% of the specified capacity. If the manufacture says the battery has a 2.1Ah (2100mAh) capacity, then only about 2.1 times 0.8 or 1.68Ah (1680mAh) should be used from the full pack before recharging. This 80% capacity recommendation has nothing to do with the C rating. It is just a recommend practice to increase the longevity of Li-Poly batteries that do not accept deep discharging very well and deteriorate rapidly if abused.

One last point; Motor batteries versus receiver batteries

Some batteries can sustain high discharge rates. Others cannot.

Those used as transmitter *or* receiver packs typically are made for low flow/amp rate *cells,* while those made for motor packs can sustain higher rates.

Having a 600mAh pack does not tell you if it is a motor pack that can put out 6 amps, or if it is a transmitter *or* receiver pack that would be damaged if you tried to pull power at 6 amps. It is enough to say that they are different.

Clearly, a motor pack could be used for a transmitter *or* receiver job, but a transmitter *or* receiver pack should not generally be used as a motor pack.

It is best to size your battery packs so they run somewhat below their maximum C rating. You will stress them less, and they will last longer.

For example, if your motor needs a pack that can deliver 10 amps, getting a 1000mAh pack that is rated for 10C (10 amps) will meet the specification, but it is running at its limit. A 15C rated 1000mAh pack would be better, or perhaps a 1300mAh 10C pack. In either of these cases, the pack will be less stressed and should handle the load much better over the long term.

A comment on voltage versus amperage

We often talk about watts *in* *per* pound as a good starting point for sizing power systems for our planes. But you can get to the watts *in* you want in two ways.

If I am flying a 5-pound plane and would like good aerobatic performance, 100 watts *in* *per* pound is probably a good target. If the plane is 5 pounds, I need a battery/motor/prop combination that will produce *and is capable of sustaining* 500 watts *in*.

Now, how do you get to 500 watts *in*? I am going to use round numbers here, so forgive me if the multiplication is a tiny bit off.

While a 3-cell Li-Poly has a nominal rating of 11.1V, under load its voltage will drop closer to 10.*5* volts. I am going to use 10.*5* volts to represent a 3-cell pack.

If I want 500 watts *in*, I need *500 divided by* 10.*5* volt*s or about 48* amps out of my battery pack.

Another way would be to use a 6-cell pack, *21* volts, and draw *500 / 21 or about 24* amps. That also gives me 500 watts *in*. This can be a single 6S *Li-Poly* pack, or it can be two 3S packs hooked up in series. They sell connectors just for this purpose. *Also, Anderson Power Pole (APP) connectors can be easily configured into a series configuration.*

You will *read and hear* various opinions as to which approach is better, high voltage or high amperage. I find most experienced power system designers will favor higher voltage and lower amperage.

There are a variety of reasons:

In order to handle high amps you need BIG FAT wires. They are heavy and can be a bit hard to handle.

You need a BIG ESC rated for high amps. They are expensive*, but high voltage ESCs are also expensive*.

Batteries are rated in amp hours *(Ah)*, meaning how many amps they can deliver *for one hour*. The higher the amp draw, the faster you drain them.

We have choices when we are producing 500 watts *in*.

A 3S 2500mAh pack *using the 80% safe rule for Li-Poly safety and longevity has a useful capacity of 2000mAh or 2Ah. When being discharged at about a* 50 amp *constant draw*, *it will be emptied in about 2.4* minutes. You would need at least a 20C pack. *2.5Ah times 20C = 50 amps* A 25C or 30 C pack would be even better so *that* you are not running the pack at the edge of its capabilities.

A 6S 2500mAh *Li-Poly* pack *that is drained of 2000mAh at 21* amps will last *5.7* minutes *at a constant 21 amp draw*, and you get the same 500 watts *in*. For this set-up you could use 10C to 15C packs, which typically cost less than 25C *or* 30C packs.

You could go to *a* 5000mAh 3S pack for longer duration *at a 50 amp draw*, but typically a 5000mAh 3S pack costs more than *the* two 2500mAh packs you would use to make the 6S pack.

Chargers: There are lots of fairly good and reasonably priced chargers that will charge a 3S *2500mAh* pack. If you get two of them you can charge the two 3S packs in an hour or less.

The chargers that can handle a 6S pack are much less common and can be pretty pricey. You get one of these chargers and you charge your 6S pack in about an hour.

There are a variety of ways to get to the power level *in that* you want. The different approaches have different cost factors.

A 6S 5000mAh pack can be pretty pricy. But four 3S 2500s, *that can be joined into a 6S2P pack that has the same voltage and capacity as a 6S1P 5000mAh pack,* might be a lot less expensive simply because *the 3S1P 2500mAh pack* is a much *more* commonly used pack. You can take those four 3S 2500mAh packs and use them to fly smaller planes. That big, fat 6S 5000mAh pack is only going to be good in a big plane.

Other Resources

Basics:
http://www.modelaircraft.org/mag/FTGU/Part8/index.html

Lithium Batteries
http://www.rchobbies.org/lithium_battery_breakthrough.htm

Lithium Balancers and Balancing Chargers
http://www.rcgroups.com/forums/showthread.php?t=599287

New Electric Flyer FAQs
http://www.ezonemag.com/pages/faq/a105.shtml

A series of posts on electric power system basics
http://www.wattflyer.com/forums/showthread.php?t=1933

http://www.rcgroups.com/forums/showthread.php?t=417868

MotoCalc
MotoCalc will tell you everything you need to know: Amps, Volts, Watts, RPM, Thrust, Rate of Climb, and much more! It is a popular tool for predicting the proper motor, prop, *and* battery pack for electric planes.
http://www.motocalc.com/

The Great Electric Motor Test
http://www.flyingmodels.org/motortest/index_e.htm
(Note: This is an old test and many of the motors and props, even though they still have the same designations as noted in the test, have been changed, invalidating some of the data.)

Electric Motors Described
http://adamone.rchomepage.com/guide5.htm

Drive Calculator
http://www.drivecalc.*de/*
Available for Windows, Max and Linux operating systems.

Lithium Battery Chargers -
Balance chargers versus external balancers

Lithium *polymer batteries have the advantages of low weight and high energy density*, but they *require* extra care *and caution*. We have *learned* that packs with two or more cells can get out of balance. That means that one cell tends to rundown lower or tends to charge higher. *When* charging through the power *leads* that connect *the battery* to the ESC*, the charger* only reads the total pack voltage. *T*he charger *then* charge*s* the pack to the expected *pack charge termination* voltage, for Li-Poly packs that would be 4.2V per cell. Therefore, when charging through the power *leads*, the charger will take a 3-cell Li-Poly to 12.6V, regardless of the individual cell voltages. If one cell is low and one is high, that could result in one cell perhaps being *over*charged to 4.3V or one being *under*charged to 4.1V, for example.

Over many cycles this differences will build up. The most benign outcome is a loss of pack performance. A more serious outcome could be that the low cell will drop below the critical 2.5V level on discharge and be damaged, rapidly degrading the pack. The more serious issue could be that one cell gets seriously overcharged getting well above the desired 4.2V *maximum* charge *voltage*. This can result in pack failure or can cause the overcharged cell to "vent with flame". This is ungood. :-O

Balancers

For the past 18-24 months we have seen a flood of pack balancers that will bring the packs into balance to maintain an even charge across all cells. To use these balancers you need a compatible balance plug on the pack. Assuming you have this arrangement, a balancer can help prevent the above situation. If you are happy with your charger and don't feel the need for a new one, a balancer is a good investment. They run from $20 to $50 with a variety of features.

The balancing benefit is significant but it need not be critical to every charge cycle. Packs don't go out of balance THAT fast. It might happen over 10 cycles or 20 cycles and it builds up over time. Using a regular *Li-Poly* charger that charges through the power *leads* is fine, if you balance every few charges that *could* be adequate. Just be sure to do it and you have to have a way of being sure you are doing it across all your packs.

Note that a balancer can only drain power, so it does reduce the overall charge level of the pack, it does not bring up the low cells. But I don't think that is a big deal.

Balancing Chargers

There are two features being discussed here, charging and balancing.

Some chargers are combined with balancers. They charge the pack to the desired level, then the built in balancer bleeds down the high cell and charging can continue. This is a good combination. It saves you from having to do this with a separate device. This type of charger provides the very significant value of keeping your packs in balance automatically. This leads to longer *cell* life, and better performance. It has some safety benefits in that it prevents one cell from being overcharged.

Balanced Chargers

Then there are balancing chargers that charge each cell individually during the charge cycle. The CellPro 4S, for example, charges each cell individually during the charge cycle. If one cell is a little slower than the others the charger compensates so higher rates can be tolerated, or so the charger companies claim. The older Cellpro 4S that I have has a safe charge cycle that charges at up to 1.4C. This is a side benefit of the balanced charge process. The newer, *now discontinued,* Cellpro 4S charges at up to 3C. *The Cellpro Multi4 charger has replaced the Cellpro 4S*. If charging your packs faster *and* safely is important to you, then these types of balancing chargers are a good value. Cellpro is not the only one but it is a good example. From that respect, certain chargers, let's call them balancing chargers; bring more benefits than just balancing.

Practical use

I have 5 Li-Poly packs with CellPro balance taps. Most of the time I charge them on my CellPro charger but I also charge them on my *Great Planes* Triton charger and on an AC “wall wart” Li-Poly charger. Only the CellPro balances, but the packs get on it every few cycles so they *are* balanced on the next charge cycle. Only the CellPro charges at the higher rate. The others are limited to 1C, and I will not push them.

Cold Weather Cycle

I don't know if this is a common feature but the Cellpro 4S *and Cellpro Multi4* also *have* a cold weather cycle. It actually detects the temperature of the surrounding air. If it is below a certain level, it only charges the cells to about 95% of full charge. This has very little impact in practical use but it provides a safety effect. If you were to charge a Li-Poly pack at the field, say at 30 degrees, then not use it and take it home, as it *is* warmed the cell voltage would rise, potentially taking it over the desired 4.2V level. I cannot say how serious a concern this may be, but it seems to make sense that it could present an unrecognized problem. This charger accounts for it automatically. I am sure there must be others that do it as well.

I do feel the balancing chargers are better than balancers, BUT not enough that it should be a big concern if you don't feel you want a second charger or the higher charge rates that some of the newer ones can offer. But understanding the benefits of balancing IS important.

Other Reference Sources

CellPro discussion
http://www.rcgroups.com/forums/showthread.php?t=786192&page=2#post8863342

Notes on Lithium Batteries
http://www.rchobbies.org/lithium_battery_breakthrough.htm

Safety warning on Lithium Batteries (*dead link*)
http://www.modelaircraft.org/safetycom.asp

The Battery Clinic
http://www.rcbatteryclinic.com/

Extending Flight Times While Maintaining Balance (*proper CG*)

Changing the type or capacity of your battery pack is typically done for one of three reasons:

* You want longer flights
* You want to reduce weight.
* You want to do both

Here are some points to consider to get the most out of this change.

If you are currently flying NiCd packs, you can go to NiMH very easily. You will gain about 40% in battery capacity at the same weight. The packs are about the same size and shape so they fit easily and should not throw off the plane's balance. NiMH and NiCd packs, NiXX for short, therefore can typically be interchanged easily. I have eliminated virtually all my NiCd motor packs and replaced them with NiMH packs.

If you go to lithium *polymer* batteries you can either make your plane lighter or you can maintain its weight but double, triple or quadruple your battery capacity. Lithium *polymer* batteries have about 4 times the capacity per ounce as compared to NiCd packs. Here are some steps to consider BEFORE you buy the new pack:

Where is your battery pack located?

If your battery is forward of the CG, the *fore and aft* balance point, then its weight is helping to balance the plane. If you go to a pack of a different weight, you MUST rebalance the plane or it won't fly well. For example, a lighter pack will shift the CG toward the rear, which may make the plane difficult or impossible to fly. You must keep the plane in balance so that the CG, center of gravity, the *fore and aft* balance point, is in the right place.

This also applies *when* going to heavier packs, as they will shift the CG forward. A slight shift forward might not be a problem if you are adding voltage, as the more powerful pack will drive the motor faster which may mask a slight change in balance. A more forward CG can make the plane more stable. For example, I shift between 6 and 7 cell NiMH packs in my Aerobird. The CG moves a little forward with the 7-cell pack but not enough to seriously affect the way the plane handles. Optimally, you want to keep the CG in the same location.

From here on I am going to assume you are going from NiXX packs to lithium *polymer* packs, as this is what many are doing and the *change* that takes the most planning.

Before you buy that new pack:

* Weigh your current battery pack. A food scale or a postal scale is fine. Many post offices in the US have self-service scales. That’s great for weighing stuff. *Measure* it to the nearest 0.1 *of an* ounce. Write it on the pack so you won't forget it.

* Now look at the space in the plane. Can the new pack go in the same or almost the same place as your current pack? You can account for a location shift by changing the amount of weight you add to the new pack.

Now decide on your goals based on what you can do in this plane and how much money you want to spend.

1) Keep the weight the same and spend more money - Get a pack that fits in the current space and weighs the same as your current pack - Now you can use the new pack and your current packs interchangeably. Good deal! However, lithium *polymer* packs are different sizes and shapes than NiXX packs so this might be hard to do. If it is close, you might be able to modify the battery space to allow the new pack to fit. A 600mAh NiCd pack weighs about the same as a 2000mAh to 2400mAh Li-Poly pack, but the Li-Poly may cost more. Prices are dropping all the time and 4 times the flight time is definitely cool!

2) Keep the weight the same and spend a bit less - Get a pack that is lighter than your current pack and *that* will fit in the same or close to the same location, perhaps with minor modifications to the plane. Maybe you go from a 600mAh NiXX pack to a 1300mAh lithium *polymer* pack rather than a 2400mAh pack. This will probably have a better chance of fitting where your NiXX pack fits. Great! Add weight to the pack so it weighs the same as your NiXX pack. You can still use both without serious modification to the plane. Good deal!

3) Make the plane lighter - If you can move stuff forward in your plane so that a lighter battery can balance the plane, you can avoid the need to add weight. Now you have a higher capacity battery pack AND your plane is lighter. Lighter planes generally fly better. The only problem with this approach is that your current "heavy packs" may not be able to be used anymore unless you can leave space to adjust their position rearward.

If it won't fit, can you modify the space to make it fit?

If you remove foam, consider reinforcing the space with tape or glue and *Lite-Ply* as you have removed some of the structure of the plane. Can you cut a hole in a former so the pack fits under it? Make sure you reinforce to account for any cut away structure. By the way, tape, glue, balsa or plywood add weight so you need take these into account. Cut a little, set some reinforcing in place but don't glue it. Position the pack and test the balance of the plane; adjust accordingly. Be sure you pad the pack in balsa or plastic planes so that a crash will not likely damage the pack. Lithium *polymer batteries* cannot take the physical abuse that the NiXX *or Lithium Iron Phosphate* packs tolerate.

If modifying the plane to move the pack forward won't get it done, then see if you can move other things in the plane to shift their weight forward. Some people have the receiver under the wings. Move it forward and it will help to balance the plane and you won't have to add as much weight to the lithium *polymer* pack. Also see if you can move the ESC forward. Move any excess wire that you have bundled to the forward area. Wire has weight.

If you have any components, like the receiver that sit behind the CG, moving them forward will make a huge difference.

If you can move your electronics forward enough *so* that you can balance the plane without the battery pack, then you can set the battery directly over the CG. Now it doesn't matter which battery pack you use, as the weight of the pack will not shift the balance of the plane. You can interchange packs all you like.

When I rebuilt one of my sailplanes after a crash, I positioned my servos, receiver and battery to more forward locations than the stock recommendation. As a result, I made the plane about 12% lighter with no other modifications. That made a HUGE difference in how it flew.

I then made a removable motor for it and positioned it on a pod that sat right over the CG so I could put it on or take it off without changing the balance of the plane. Likewise I placed the battery right over the CG. With the motor and battery mounted, the plane was much heavier, but it stayed in perfect balance whether they were on or off the plane.

There are other considerations related to lithium *polymer* batteries. You need a special charger and charging procedures. You MUST protect them from damage, as they cannot take the same *physical* abuse as NiXX *or Lithium Iron Phosphate "A123"* packs. But these are covered elsewhere. This one is just about maintaining balance (*the correct CG*).

Clear Skies and Safe Flying!

* See if you can buy a lithium *polymer* pack that is the same weight as your current battery pack. If you can, and you can afford it, you are all set and have two to four times the flight capacity for longer flights.

Understanding the Electronic Speed Control

Amended - 11/2008

When we look at model airplanes that have electric motors, as opposed to liquid fuels, the things we notice first are the quiet electric motor and the battery. However there is a component that sits between them called the electronic speed control *or ESC* that is really the master control point for all power in the plane. We are going to look at its make-up and how it does its job.

On the surface we can see that the electronic speed control, the ESC, takes over the function of the throttle servo that would operate the carburetor in a glow or gas powered plane. Just as the throttle servo controls the speed of these wet fuel motors, the ESC controls the speed of the electric motor. But there is more to it than that.

The first thing that we want to recognize is that there are two different kinds of ESCs. *They* are specific to the type of motor they control. There are brushed motors, such as the Speed series or the Mabuchi motors, and then there are the brushless motors. Each type of motor needs a different electronic speed control.

Understanding the Wires

When you look at an electronic speed control, you notice that you have three sets of wires. Typically two sets of thick wires and one set *that* looks like a servo wire.

Two of the thick wires, typically black and red, connect to the battery. The ESC will usually be marked to *indicate* which are the battery wires. They connect to the battery red-to-red and black-to-black.

A second set of wires, typically thinner than the battery connection wires, has a plug on the end that looks like a servo plug. This will be connected to the receiver and *sometimes* serves two purposes; *powering* the receiver and *getting* signals from the receiver.

If we look at the wires on this plug they usually run from a dark or black wire on one side to a light or white wire on the other side. I am going to use black, red and white for this discussion. Yours may be dark brown, orange, yellow or something similar.

The black and red wires *may* feed power to the receiver *if the ESC has a battery eliminator circuit (BEC) that is being used*, which in turn distributes power out to the servos and other accessories that are plugged into the receiver. Note that the red wire is in the center. This is the power wire. Since it is in the center you can insert the plug into the receiver either way and nothing bad will happen. You won't get any response from the servos if you put it in wrong, but you won't damage anything. Note that, on some older systems, particularly Airtronics radio systems; the red wire was on the *outside edge of the three wires*. If you plugged it in the wrong way it could damage the receiver and possibly the servos. However the center red design has been fairly universal for many years.

The third wire, the white wire is the signal wire that sends commands from the receiver to the ESC to tell it how to control the motor. As you move the throttle control on your transmitter, the receiver gets the command and passes it up the white wire to the ESC so *that* it knows how much speed you want from the motor.

There is a third set of wires that go to the motor. The ESC is usually marked to show which wires are the motor wires. If this is a brushed motor ESC then there will be two wires, typically red and black. On a brushed motor ESC, if we connect red-to-red on the motor, and black-to-black, the motor will turn in the expected direction. If we reverse them the motor will spin in the opposite direction.

On a brushless ESC, you match color to color as well. However if the colors don't match*, it really doesn't matter*. *To get the motor to spin in the direction* you need, observe the direction of the motor. If it is spinning in the wrong direction, reversing any two wires will correct this.

Note that on some older brushless motors there were additional wires that attached to a sensor in the motor. However, unless you have an old motor and ESC combination you won't see that on any of the current designs.

Some ESCs have an integrated switch. In most cases this will allow or prevent the motor from running and pass or block power to the receiver. However it typically does not stop the flow of current from the battery to the ESC. In fact, even if there is no switch there is always current flowing to the ESC, which will drain the battery.

It is for this reason that you should never leave your battery connected when you store your plane. This small current drain will take your battery to zero charge over time. If you are using NiCd or NiMH, the damage may be minor. If you are using Lithium *polymer* batteries, you lithium *polymer* battery pack will likely be ruined. Don't leave your battery connected unless you are preparing to fly.

***Servo* Connectors**

The connector *or* plug that goes to the receiver is standardized. It is the same wire scheme and plug type as is used for the servos. Today all makers, except Futaba, use *a* universal plug.

On the Futaba J plug you have the same wiring scheme but there is an extra tab on the plug that insures the connector is inserted properly into the receiver. If you have a receiver that accepts this slotted plug it will also accept universal plugs. However if you have a receiver that accepts the universal plug, then you will need to trim off this tab with a hobby knife or you can sand it off. Once trimmed, the plug will work fine.

Battery and motor connectors are not as simple.

There is an emerging standard for *the* motor *and* ESC connection on brushless motors. The connectors are round and are called bullet connectors. Most brushless motor *and* ESC makers seem to be using these now, so on brushless motors this connector standard seems to be established. However, for brushed motor connections there is no standard.

On the motor side we have the option of not using a connector, as we can solder the motor and ESC wires together. This works fine if you don't plan to remove the motor or the ESC and it gives the best connection. However, if you do have to remove one of them for service, you will need the soldering iron in order to take the connection apart.

On the battery side we always use a connector so that we can remove the battery for charging and storage. When flying electric planes it is common to have several battery packs. The connector allows us to remove one pack and insert a fresh one while the first is charging.

Whatever battery or motor connector you use, make sure that is has a current, amp, rating that is larger than what the motor is likely to pull. The reason the wires for these links are thicker is that the battery has to deliver high current to the motor as opposed to the relatively small current that goes to the receiver. If the connector can't handle the flow, it will heat up and potentially be damaged. Likewise, if the connector can't handle the current the motor will never develop full power. Too light *of* a connector can also cause a serious voltage drop.

This lack of standards leads to situations where you buy a motor that has one connector, your battery has a different connector and your ESC has a third type. Or, as seems to becoming more common, none of them have connectors and you have to add your own.

My suggestion is to standardize *your* connectors. Once standardized, any motor or battery connection that doesn't have your standard connector gets a connector replacement. It takes time and *sometimes* soldering but with one standard, all of your batteries will work in any *of your* plane*s* for which they are appropriate and you can move motors and ESC around as you desire.

This will also simplify your battery to charger connections. One or two adapters for your charger will handle all of your batteries. Just make sure the connector you use can handle the current.

I have three standards. For brushless motors, I use the bullet connectors. For brushed motors and batteries in very small light planes, where the current will typically be under 5 amps, I use the red BEC connectors. These are sometimes called GWS connectors, as they are common on GWS motors, batteries and ESCs. They are small and light and are well suited for small light planes.

For my high current applications I use the Deans Ultra connectors. They can handle very high currents, are easy to solder and can be easily removed and reused. However, there are many other high current connector that are equally as good. As long as it can handle the current flow, it will be fine.

Sizing an ESC

Electronic Speed Controls are sized according to how many amps they can control and the voltage that they can handle. You may see an ESC marked as 20 amps and 7-10 NiXX cells or 2-3 cell Li-Poly. That says it can handle a 20-amp flow using a battery pack that ranges between 7.4V and 12 volts. If you use it with a motor/battery system that is outside this range it will likely fail. When it fails it may simply not run the motor or it may also cut power to the receiver, which will lead to a crash.

You size your ESC according to the motor and the battery you are using. I won't go into how we determine what motor and battery will need*ed*. That is covered in another article. It is enough to say that, if your motor is going to draw 20 amps you will need an ESC that is rated for at least 20 amps. There is no problem having an ESC that is rated for more amps than you need, but an ESC that is rated below the expected current load will likely lead to a failed ESC.

I recommend that you always have at least a 20% margin between the amp requirements of your motor and the rating of your ESC. This way you will know *that* you will not be overloading the ESC. A bigger margin is also fine.

The same goes for the voltage. Use your ESC outside the voltage it is designed for and you can expect it to fail.

Your ESC *could* have an integrated battery elimination circuit, a BEC. This is the part *of the ESC* that delivers the power to the receiver. Always check the specifications for the BEC. While the ESC might be able to handle 14.4 volts, the instructions may say that for uses above 11.1V you may have to disable the BEC. There is a complete article on the BEC, so I won't go into it here. Let's just say you need to check this.

How the ESC controls the Motor

Motors are rated by Kv, which means the number of revelations the motor will turn when you apply 1 volt of electricity. *An unloaded* 1200 Kv motor will spin at 12,000 rpm if you apply 10 volts.

From this you might imply that the ESC changes the voltage to the motor in order to change the speed of the motor, but that is not the case. If you look at the specifications for your ESC you will probably see a frequency number. This might range from 2 KHz to 12 KHz or higher. This is related to how fast the ESC can pulse power to the motor. You see your ESC is not a variable resistor that adjusts the voltage to the motor, it is a fast switch that *switches* power *on and off* to the motor.

You can think of this as a duty cycle control. How long will the ESC leave the power on *until* it turns it off? Then, how long will it be off before it turns it back on? There is no need for you to know this cycle time, only that for every on cycle your motor is getting *almost* the full voltage *and current, as determined by the load on the motor, from* your battery.

I take the time to explain this because people mistakenly believe that if they run their motor at partial throttle they are sending reduced voltage *and current* to the motor. If the motor is not supposed to get more than 7.4 volts and you put in an 11.1V battery, running the motor at *a partial* throttle *setting* does not reduce the voltage *or current* to the motor. It is getting 11.1V hits every time the ESC switches on. On a brushed motor that is receiving too much voltage, this will typically produce arcing, which will burn up the brushes on the motor. In addition to this arcing on brushed motors, this higher electric pressure may push too much current that will overheat the motor.

If you have had a motor "burn up" even though you usually ran it at a partial throttle setting, this may be the reason. Understanding how the ESC controls your motor will help you diagnose problems. *Also, running an ESC at partial throttle is less efficient than at full throttle and heats of the ESC more than running at full throttle.*

Note also that, since the ESC is switching power on and off it is also producing electromagnetic pulses, or radio waves. The electronics in the ESC will typically be designed to reduce or shield some of this radio wave noise, but it can't block it all. This is why we recommend keeping the ESC and the receiver as far apart as possible as this ESC *radio frequency* noise can interfere with the receiver. If you are getting "glitching" or odd pulses to your servos, these may be coming from ESC *radio frequency* noise *that is* bothering the receiver. Try moving things around.

Other Components in the ESC

I am going to address these in later articles, but there are typically two other components that are integrated into your ESC. We already mentioned the BEC. The other is the LVC, the low voltage cutoff. These are not directly involved in controlling the speed of your motor, but as you will see in the articles that are focused on these that they are very valuable parts of your ESC that you will want to understand.

Summary

The electronic speed control is the power system controller for your airplane. Its various components *may* distribute power to the receiver*, automatically turn off the motor* and control the speed of the motor. Understanding how it works will give you the ability to properly size and install the ESC and to diagnose problems in the system.

AMENDMENT:

MY MOTOR WON'T RUN – WHAT'S WRONG?

A tip for new electric pilots - Setting the throttle to zero

Before most Electronic Speed Controls, ESCs, will allow the motor to run they require that you move the *throttle* stick to zero throttle. But, is it really at zero?

There is a trim on the throttle channel, just like the other channels. On glow planes they use this to set the idle, so the motor won't shut off when they go to zero throttle position. In other words the throttle isn't really at zero.

But we don't have to worry about idle on electric models. We want the throttle to be able to go to zero.

If your throttle trim is set to the center, then your throttle channel may not really be going to zero. This can result in your ESC not arming and not allowing your motor to run. If this happens to you, move that trim on the throttle channel until it is all the way down, to zero. Now see if the ESC will arm and the motor will run.

This came up because a friend with a new Radian had this problem. When he called for support, they thought it was a defective ESC and sent him a new one. But that new one did not work either. He called me. Well, I have been down this path before, so after trying a few other things, we moved the trim all the way down.

Bingo! His motor now works and all is right with the world.

Just a tip from someone who has seen this problem a few times before.

Futaba transmitters require that the throttle servo position switch or setting in the computer controlled transmitter needs to be placed in reverse to work with most brands of ESCs. Consult the transmitter manual to learn how to do it. Remember to always remove the prop when setting up the ESC. Get the motor working without the prop on. Do not run the motor for extended periods of time without a propeller attached. It can cause damage to the motor, and there is just no reason to do it.

The Low Voltage Cutoff Feature Of Your ESC

Many electronic speed controls include a feature called the low voltage cutoff circuit, the LVC. The LVC watches the voltage that is being delivered by the battery. When it gets below a certain level, it will cut power to the motor to preserve power for the radio system. This will allow you to keep control of the plane and land it in a glide.

The power drawn by your receiver and servos is a tiny fraction of what the typical electric motor draws. As the battery drains it will exhibit a voltage drop. You may feel this in the way the plane flies. The plane may become sluggish or it may not be able to climb under full power. This is a clear indication that the pack is getting low.

A battery that can't sustain voltage when the motor is on, can still provide plenty of power for the flight electronics and may be able to do so for quite a while, but don't test it. If your motor cuts, enjoy the glide, but set up to land as soon as possible. I always teach new pilots how to glide their planes so if the LVC cuts the motor *power*, they don't panic.

If you practice flying your plane with the motor off, then an LVC cut will be no big deal. You might even find you enjoy gliding, which can extend your flying time. I often glide and thermal my electric planes just for fun.

LITHIUM BATTERIES CHANGE THE ROLE OF THE LVC

If you drain NiCd or NiMH packs too low, usually there is little damage. Just bring them back to charge a little slower than normal. If you drain a lithium *polymer* cell below *a* 2.5V resting voltage, typically the cell will be damaged. In this case the LVC is protecting your plane and your battery packs.

Most lithium *polymer* friendly ESCs will cut the motor off if the pack voltage drops below 2.7V to 3.0V per cell under load. *Today's higher C rated Li-Poly packs require an even higher cutoff voltage. 3.3v per cell has been suggested as the cutoff* *voltage for these high C rated cells*. At this level there is very little useful charge left in the pack and the voltage will continue to drop fast.

Note that when you cut the load of the motor the voltage will likely pop back to 3.1V, 3.2V or even 3.3V per cell. If you check your batteries after you land, you may think that LVC has malfunctioned, but it has not. The battery may be 3.3V *per* cell resting but it can't sustain it with the motor running.

One thing you might want to be aware of is that the voltage sag will be less at lower throttle settings. If the LVC cuts the power at a particularly bad time, you may be able to get a short burst of motor operation at a reduced throttle setting. A short run at half or quarter throttle may be all you need to get you over that fence, past that tree or properly aligned with *the* runway. Don't push it by trying to extend your flight with lots of short bursts. However, if it will help you avoid a crash, two short runs, to save the plane, are worth the risk to the battery pack.

CONCLUSION

The LVC was put there to protect the *on-board* radio, but if you are using Lithium *Polymer* batteries the LVC can protect them too. It is best to be sure your *ESC's LVC* is lithium *polymer* friendly. That means either that it can be set manually, or that it senses how many lithium polymer cells you have and sets *LVC* automatically. Even if it is not designed for Lithium *Polymer* cells, if you can set the cut-off at something above 2.75V per lithium *polymer* cell, then you should be OK.

Understanding how the LVC works will make it your friend.

The Role of the BEC in Your ESC

In the world of electric motors the electronic speed control, ESC, takes the place of the throttle used on fuel-powered planes. It regulates the speed of the motor by *turning* the power to the motor *on and off very rapidly* to achieve the desired motor speed. However most ESCs also have two other functions, the LVC and the BEC.

As describe earlier, the LVC, low-voltage-cutoff circuit, will cut power to the motor and preserve power to the radio system so *that* you can land your plane safely when the motor battery is getting too low. In the case of lithium *polymer* batteries, the LVC, can also save your battery packs by preventing them from getting too low. If you started with NiXX packs and have switched to lithium *polymer* packs, be sure your LVC is set properly or you could damage your lithium *polymer* packs.

The BEC, the battery elimination circuit, supplies power to the receiver and the servos. It is the BEC that will be the main focus of this discussion.

The name, battery elimination circuit, comes from the fact that, in the "old days" of electric planes, you had a battery pack to power the motor and another one to power the receiver *and servos*. In order to save weight, the BEC was introduced to eliminate the need for *the* receiver battery pack.

In most of our radio systems, the receiver is designed to operate between 4 volts and 6 volts. To match this, the typical *linear* BEC supplies power to the receiver at about 5 volts by stepping down the motor battery voltage. However the higher the voltage of the motor battery, the harder the *linear* BEC has to work to get the voltage down to 5 volts. In doing this work, the *linear* BEC generates heat. The greater the voltage reduction, the more heat the *linear* BEC generates. As a result most *linear* BECs have to be disabled if the motor battery pack is over a certain voltage. ESCs that are designed specifically for high voltage use often do not have an integrated *linear* BEC *or they may have a switch mode BEC. To learn the differences between a linear BEC and switch mode BEC read the following*.
http://www.dimensionengineering.com/switchingregulators.htm

Basically a switch mode BEC regulator works by taking small chunks of energy from the input voltage source and moving them to the output. A switch mode BEC can be up to 85% efficient, power more servos and produces less heat. A switch mode BEC is also more expensive and increases the cost of any ESC that uses one instead of a linear BEC.

BECs are also rated by how many amps they can deliver to the receiver. The greater the number of servos installed, the greater the amperage the BEC must deliver and the more heat it generates in the process*, if it is a linear BEC*. However, with most integrated *linear* BECs, the higher the voltage of the motor battery pack the lower the amperage the *linear* BEC can deliver. This is often where problems occur. It is this heat that leads to the need for a compromise as to how many servos an integrated *linear* BEC can support.

For example, if the motor pack is *an* 8.4V *type*, then a given *linear* BEC might be able to support 4 servos. If the motor battery voltage is higher, say 11.*1* volts, then the same *linear* BEC may need to be de-rated to handle only 3 servos. Since more heat will be generated by the larger step down from 11.*1* volts to 5 volts, the amp load has to be reduced or the *linear* BEC will overheat.

Note that the voltage rating for the ESC may be different than the voltage rating for the BEC. Your ESC may be rated for 14.8 volts but the BEC may have to be disabled over 12 volts, and you will have to power the receiver separately *using a receiver battery park or external switch mode BEC*. If you don't take note of this and pop in a four-cell Li-Poly, your ESC may be fine but your BEC may be heading for a failure, resulting in a crash.

According to Dimension Engineering, a maker of *switch mode* BECs, "Many people don't realize that their ESC's BEC rating is misleading. With the linear BEC built into most speed controls, the current rating decreases as pack voltage increases. For example, several popular 25A ESCs with "3A" BECs are only capable of supplying 0.5A when running from a 3s *Li-Poly* pack".

If you are flying a RTF or "receiver ready" model, there may not be *ESC or BEC* documentation included. As an example, the manufacturer of the plane may designate that the plane takes an 8.4V pack. At that voltage the included BEC may be fine. However, if you decide to pop in a three-cell Li-Poly, a problem may only be a launch away. The BEC may do fine for a couple of flights, or maybe 5 minutes or may fail 100 feet out, and down you go.

We also have the variable of which servos are being used. Different servos draw different amounts of current. If the current draw gets too high, the BEC will get too hot causing a thermal shutdown of the BEC. This protects the BEC and prevents a fire, but cuts the voltage to the receiver. The net effect is that you lose all power to the radio system and you lose control of the plane.

In the case of an overheated BEC, if there is enough cooling air going through the plane, the BEC may come back quickly as it cools. This could look like a radio glitch, but it could be the *linear* BEC operating on the edge of total failure.

If your ESC is very hot when you land, the cause could be the *linear* BEC operating at the edge of its capacity. When we see these glitches, we often think the problem is the radio system, but in fact the cause could be the BEC.

A CASE STUDY

A pilot was flying a new Spektrum 2.4GHz system. All was fine *until* the plane suddenly went dead and crashed. All sorts of speculation were offered about what the cause could be and much of it was focused on the Spektrum 2.4GHz system. After the plane was recovered, everything seemed to work OK so it must have been a radio hit, right? However, due to the diligent work of the pilot, it was determined that the *linear* BEC had failed due to overload. You can read the actual account at this link in posts 2986 to 3006.
http://www.rcgroups.com/forums/showthread.php?t=604621&page=200

This is not the only account of this type that has been reported, but this was one that was worked out over a short time with a very clear outcome. Note also that the pilot had to run his test for several minutes before the failure appeared. Thus, everything seemed fine at first; it seemed that the *linear* BEC was handling the load. But, over several minutes heat built up in the BEC. Combine this with the heat from the motor and the battery and, perhaps not enough cooling airflow and the *linear* BEC shut down.

BE COOL FOOL!

With good airflow a BEC overload may be avoided. Regardless of what radio system you are using, make sure you have enough cooling air going through your electric plane. This is especially true of foam planes, as the foam acts as an insulator.

You may have a cooling air vent in the front somewhere, but the heat can't get out unless there is an exit air hole large enough to allow good airflow. If you are pushing the limit on any part of your power or radio system, not enough cooling air can cause damage or failure to your motor, ESC, BEC or battery packs. The receiver could overheat or you could cook your servos.

How you fly your plane can also cause heat build-up. For example, an Easy Glider that is flown for 1 minute to get to altitude might have enough airflow to eliminate the built up heat. If you fly it constantly for 10 minutes, the heat build up could be enough to cook your BEC, your battery pack, or some other part of the plane.

Be cool fool, and make sure you have enough airflow in your plane. If your battery is very hot, or if your ESC is very hot, you may need more cooling.

OTHER CAUSES OF BEC PROBLEMS

You could be configured properly. Your BEC may be rated to handle your servo count and you could have plenty of cooling air but still have problems. If you have a servo pushrod that is dragging or is otherwise placing a high load on the servo, this can increase the amp draw of that servo. If that servo gets stuck, the amp draw will go way up!

Servo loads are expected to be variable. A servo will move, put a load on the BEC then come back to neutral and the current draw will drop. In between loads, the BEC has a chance to cool. However a jammed servo will draw a lot of power and that draw will be constant. You can see why it is very important that your servos move freely, without binding. Check those control rods for kinks, obstructions or things that could get in the way.

ENTER THE COMPUTER RADIO

In the past it was common to have 2 ailerons run off of one servo *via a torque rod or bell-crank system*, so three servos were typical *for* a 4-channel electric plane. With more and more people using computer radios, there is a tendency to put 2 servos on the ailerons meaning more load on the BEC.

Also, with a computer radio it is easy to add a little aileron to rudder mixing, moving 3 servos at once. Now add a little up elevator in the turns and all four servos are pulling power. Go to a full house electric sailplane, with flaps following ailerons, rudder mixed in and a little up elevator in the turn and you now have 6 servos, all *of them* moving at once. We begin to see how the *linear* BEC can become challenged to keep up.

WHAT IF YOU NEED MORE?

If you need more power than the integrated *linear* BEC in your ESC can supply, or if your motor battery voltage is higher than the BEC can handle, you will need to disable the integrated *linear* BEC and put in a separate receiver pack or a separate *switch mode* BEC. Many companies make after market *switch mode* BECs that can handle these higher voltages *and*/or higher servo loads.

Note that there are different kinds of circuits that are used to create the BEC function. There are linear BECs, which seem to be primarily what is found integrated in with the ESC. These seem to be low cost, but *they* are more affected by the voltage of the motor pack. Then there are switch mode BECs that seem to tolerate these higher pack voltages better than the linear BECs. It appears many of the after market BECs are of this type.

Regardless of what type you have, follow the instructions carefully or risk losing your plane. Be sure to provide plenty of cooling air.

Listed below are some examples of after market BECs.

The Ultimate BEC
http://www.hobby-lobby.com/ubec.htm

Novak 3 amp BEC
http://www2.towerhobbies.com/cgi-bin/wti0001p?&I=LXSGC1&P=7

For very large servo counts - 6 amps
http://www.horizonhobby.com/Products/Default.aspx?ProdID=SQBDBEC008V

Dimension Engineering has several BECs
http://www.dimensionengineering.com/

The SMART BEC - Combines BEC and LVC that is Lithium *polymer* aware http://www.dimensionengineering.com/SmartBEC.htm

SUMMARY

The ESC is the heart of your electric power system. The BEC is the part of the ESC that powers your radio system. Keep it cool and make sure you read the instructions so *that* you don't overload it. Forget these tips and you may be picking up pieces of your plane, wondering what caused that crash.

Sizing Power Systems for Electric Airplanes

Revised 9/8/07

This may get a little technical but I will try to keep it as simple as I can. I will draw parallels to cars and bicycles in many places. Most people can relate to these and know at least a little about how they work. I will use round numbers where I can and will use some high level examples.

If you are an engineer you will see that I am taking some liberties here for the sake of simplicity. I will go through the parts of the power system, then, toward the end, I will show you how we tie these all together to come up with a complete power system.

POWER = WATTS

I will be using the terms Volts, Amps and Watts throughout this discussion. Let me define them.

Volts = the pressure at which the electric energy is being delivered. *It is similar to* pounds per square inch or PSI in a fuel system or water from a garden hose. Volts are about pressure. It says nothing about flow. You will see volts abbreviated as V.

Amps = the quantity or flow of electricity being delivered, like gallons per minute in a fuel system or that same garden hose. Amps are about flow. It says nothing about pressure. You will see amps abbreviated as A. *Internationally, I is used for amps, not A.*

Watts = V x A*, that is volts times amps*. This is a measure of the energy or power being delivered. This is how we measure the ability of electricity to do work. In our case *it is* the work of turning a propeller to move our airplane through the air. Watts is about both pressure and flow. This serves the same purpose as the horsepower rating of your car's engine. In fact, 746 watts = 1 horsepower. If you had an electric car, the strength of its motor could be reported in either watts or horsepower. You will see watts abbreviated as W.
If you want more depth on this, visit this thread.
http://www.wattflyer.com/forums/showthread.php?t=1933

MOTOR EFFICIENCY - Brushed vs. Brushless

Whether brushed or brushless, the motor's job is to convert electricity into mechanical motion to turn the propeller *or ducted fan* to move air. Efficiency is how we measure how much of the power, the <u>watts *in*</u>, that our battery delivers to the motor is actually turned into useful work and how much is wasted as heat. A higher efficiency motor delivers more energy to the prop, and wastes less.

A typical brushed motor, say a *typical* Speed 400, *with 100 <u>watts in</u> has a final drive efficiency, at 10 amps, of about 58%. That means that only 58% of the <u>watts in</u> actually got to do the work of spinning the prop. The other 42% was wasted energy, mostly in the form of heat.* Only *slightly more than* half the watts delivered to the *ESC and then the motor* actually end*ed* up as *the* useful work *of* turning the propeller. The rest is wasted. Motors that have a "Speed" designation, like Speed 400, are brushed motors. There are other names for brushed motors, but the "Speed" term is a common one. They are inexpensive and they work. For example, you can buy a Speed 400 motor and electronic speed control, ESC, for $30. A comparable brushless *motor and ESC* combination would typically cost 2 to 4 times that much.

Brushless motors tend to be *somewhat* more efficient. Thus you get *slightly improved* performance per <u>watt *in*</u> with brushless motors. *A typical replacement outrunner for a Speed 400 geared brushed motor would be the E-flite Park 400 920Kv. With the same 100 <u>watts in</u> as the Speed 400 brushed motor it has a final drive efficiency, at 10 amps, of about 67% and a brushless geared inrunner used to replace a Speed 400 might have a final drive efficiency closer to 70%.* Seen a different way, if you use a brushless motor, then, for the same flying performance you will use less energy, which means your battery will last longer. Or you can use a similar size and weight brushless motor *and* battery combo to get comparable performance because the motor turns more of the watts *in* from the battery into the useful work of turning the propeller.

As with many decisions we make, this is a cost benefit decision. Am I willing to pay more to get more? That is up to you.

THE BATTERY IS MORE THAN JUST THE FUEL TANK

Think of the battery as the fuel tank plus the fuel pump and a supercharger all rolled into one. It feeds *and* pushes energy to the motor. You have to look at the battery, *ESC* and the motor as one unit when you are sizing power systems for electric planes. In many cases we start with the battery when we size our systems because the motor can't deliver the power to the prop if the battery can't deliver the power to the motor.

The higher the voltage rating of the battery, the higher the pressure, like a supercharger on a car engine. More pressure delivers more air *and* fuel mixture to the engine, which allows the engine to produce more power to turn the wheels of the car.

Higher voltage pushes more electricity into the motor to produce more power, IF AND ONLY IF, the battery has the ability to deliver more electricity. Again using the car analogy, if you put a big motor in a car and *use* a tiny fuel line and a weak fuel pump, the motor will never develop full power. In fact the motor might starve and stall once you *get* past idle. Such is the same with batteries. We need voltage, we need capacity, but we also need to know how many amps the battery is capable of delivering at peak.

If we compare an 8-cell AAA *size* battery pack to an 8-cell *sub*-C *size* battery pack we get 9.6V for both packs. However the AAA *size* pack may only be able to deliver 6 amps. After that the cells will heat up and either be damaged or the voltage will start to drop fast. The *sub*-C *size* pack, also 9.6V, might be able to deliver 60 amps without damage. We have to size not only by voltage, but *also* by the ability to deliver amps to the motor. Again, think of the fuel line and the fuel pump as your image of what I am trying to explain. If the motor needs 12 ounces *of fuel* per minute to run but the fuel line can only deliver 8, the engine will starve and die.

Using our electric motors, a given motor may *pull* 10 amps (the quantity of electricity flowing) at 8.4 volts (the pressure at which the electricity is being delivered) to spin a certain propeller. We would say that the battery is delivering, or that the motor is drawing 84 watts *in*, i.e.: 8.4V x 10A. If you bump up the voltage to 9.6 volts, the battery can ram more amps into the motor, more energy to the motor, which will produce more power to the propeller. In this example, if we move from an 8.4V battery pack to a 9.6V battery pack the motor may now *pull* 12 amps. *The higher voltage* will typically spin the motor faster with any given propeller or allow it to turn a larger propeller at the same speed.

However, if you bump up the pressure too much, you can break something. Putting a big supercharger on an engine that is not designed for it will break parts of the engine. Too much voltage can over power your electric motor and damage it. There is a balance that has to be struck.

Different motors can take different amounts of power, watts, volts x amps, without damage. For example, a *brushed* Speed 400 motor might be fine *pulling* 10 amps at 9.6 volts or 96 watts *in*. However bump it up to 12 volts and ram 15 amps down its throat *(180 watts in)* and you will likely burn it out.

Our goal is a balanced power system. If you match the right battery with the right motor, you get good performance without damage to the motor. In many cases, airplane designers will design planes around a specific motor *and* battery combination so that they match the size and weight of the plane to the power system for good performance.

PROPELLERS

Propellers are sized by diameter and pitch.

The diameter of the propeller determines the volume of air the propeller will move *to produce thrust*. Roughly speaking, the diameter of the propeller will have the biggest impact on the size and weight of the plane that we can fly. Larger, heavier planes will typically fly better with larger diameter propellers.

Pitch refers to the angle of the propeller blade and refers to the distance the propeller would move forward if there were no slippage in the air. A 7-inch pitch propeller would move forward 7 inches per rotation, if there were no slippage in the air. If we combine pitch with the rotational speed of the propeller we can calculate the pitch "speed" of the propeller. At 10000 revolutions per minute, that prop would move forward 70,000 inches per minute. Doing do the math *(7"pitch x 10000 RPM)/1056 = 66.3 mph)*, that comes out to a little over 66 miles per hour.

By changing the diameter and the pitch of the propeller we can have a similar effect to changing the gears in your car or a bicycle. It will be harder for your motor to turn a 9x7 propeller than an 8x7 propeller. And it would be harder to turn a 9x7 propeller than a 9x6 propeller. The larger *diameter and*/or steeper pitched propellers will require more energy, more watts/horsepower, to turn them. Therefore, we need to balance the diameter and pitch with the power or wattage of the motor *and* battery system.

Fortunately we don't actually have to do this, as motor manufacturers will often publish suggested propellers to use with a given motor *and* battery combination. We can use these as our starting point. If we want *to,* we can try different propellers that are near these specifications to see how they work with our airplane.

Unfortunately, the manufactures and suppliers list the battery and prop combinations backwards. Horizon Hobby, which is very typical for all manufactures and suppliers, shows the following for the E-flite Power 25 BL Outrunner Motor, 870Kv - Recommended Prop Range: 11x8 to 14x7
Cells: 3S-4S Li-Po or 10–14 Ni-MH/Ni-Cd
What they don't note is that the 3S Li-Po and 10-cell NiXX use the 14x7prop and the 4S Li-Po or 14-cell NiXX use the 11x8 to keep the amp draw below the recommended maximum.

All manufacturers and suppliers, that supply data like this, have it backwards. Remember, the largest recommended diameter prop goes with the fewest number of cells and the smallest diameter prop goes with the greatest number of cells to keep the amp draw below the recommended maximum for that particular motor.

GEARBOXES

While unusual on glow or gas planes, gearboxes are common on electric planes. Their primary function is similar to the transmission on a car. The greater the gear ratio, the higher the numerical value, the slower the propeller will turn but the larger the propeller we can turn. You can use a gearbox to help provide more thrust so *that* you can fly larger planes with a given motor. However you will be turning the propeller slower *and* the plane will not go as fast.

With direct drive, that is when the propeller is directly attached to the motor shaft *with a prop adapter*, we are running in high gear (no gear reduction). *It is* like pulling your car away from the light in high gear. Assuming the motor doesn't stall, acceleration will be slow, but over time you will hit a high top end! Typically direct drive propellers on a given motor will have a smaller diameter *compared to that same motor with a gearbox installed.*

With the geared motor, it would be like pulling away from the green light in first gear. *There would be* tons of low-end power and lots of acceleration, but your top speed is reduced.

By matching up the right gear ratios made up of the propeller and, optionally, a gearbox we can adjust the kind of performance we can get out of a given battery *and* motor combination. How this is done is beyond the scope of this article.

NOW WE CAN START TO MATCH UP THE PIECES!

The simplest approach I have seen to figuring power systems in electrics is input watts per pound of "all up" airplane weight. The following guidelines were developed before brushless motors were common, but it seems to hold *up* pretty well. We will use it regardless of what kind of motor is being used.

50 watts *in* per pound = Casual/scale flying
75 watts *in* per pound = Sport flying and sport aerobatics

100 watts *in* per pound = aggressive aerobatics and perhaps mild 3D

150 watts *in* per pound = all out performance.

Remember that Watts = Volts x Amps. This is a power measurement. In case you were wondering, 746 watts equals 1 horsepower.

AN EXAMPLE!

This should be fun. Let's see where these formulas take us! We will use a 24 ounce, 1.5 pound, plane as our example. If *you* want basic flight you will need 50 watts *in* per pound or about 75 watts input to your *ESC* for this 1.5-pound plane. That is, 50 watts *in* per pound x 1.5 pounds = 75 watts *in* needed for basic flying performance. If you want a little more spirited plane, *you* could use 75 watts *in* x 1.5 pounds, which is about 112.5 watts *in*.

Lets use 100 watts *in* as the total target, just to be simple, shall we? I am going to use a lot of round numbers here. I hope you can follow.

The Battery:

If we use an 8-cell NiMH battery pack at 9.6V it will have to deliver 10.4 amps to hit our 100 watts input target (100 / 9.6 = 10.41amps) If my battery pack cells are NiMH cells that are rated at 10C then I need an 8-cell pack rated at 1100mAh to be able to deliver 11 amps. Sounds about right.

Now I select a motor that can handle 100 watts *in* or about 10.4 amps at 9.6 Volts. From experience *I* know this could be a Speed 400, a Speed 480 or some kind of a brushless motor.

We now need a propeller that will cause the motor to draw about 100 watts *in*. I don't know off the top of my head what that would be. I would go to some *manufacturer's* chart as a starting point. GWS has good charts! http://www.gwsus.com/english/product/powersystem/edp400.htm

I see that if I use a direct drive Speed 400 with a 5x4.3 prop at 9.6V then the motor will draw about 12.4 amps or about 119 watts. This would be a good candidate motor *and* prop for the plane using a 9.6V pack that can put out 12.4 or more amps. This would be a set-up for a fast plane, as that motor will spin that small prop very fast.

Maybe I don't want such a fast plane but one with a really good climb and lots of low-end pull to help out a new pilot who is in training or to do more low speed aerobatics

I can also use a Speed 400 with a 2.38 gearbox and run it at 9.6V spinning a 9x7 prop and run at about 12.8 amps for 120 watts. http://www.gwsus.com/english/product/powersystem/eps400c.htm

The larger prop will give this plane a strong climb, but since the prop speed has been reduced by 2.38 times, it won't be as fast. Spinning a bigger prop gives me more thrust but a lower top speed. This is a common strategy for 3D planes.

Back to battery packs and motors

If I shop for a 9.6V pack to be able to handle about 15-20 amps, I should do just fine and not over stress the batteries. In NiMH that would probably be a 2/3 or 4/5 A *size* pack of about 1000mAh -1300mAh capacity. Some examples here: http://www.cheapbatterypacks.com/?sid=1597196&pgid=loosecells&chem=NIMH

We view the battery and motor as a linked unit with a target power profile, in this case about 100 watts *in.* We use the prop and gearbox, if any, to produce the manner in which we want to deliver that power to the air to pull/push the plane.

If this is a pusher, I may not have clearance to spin that big prop. I may have to go for the smaller but faster prop combo.

If this is a puller, then I can choose my prop by ground clearance or some other criteria and match a gearbox to it.

See, that was easy, right? (well, sorta but ....)

But we are not done! Oh no!

I could try to do it with a 2-cell lithium *polymer* pack rated 7.4V. To get 100 watts *in* I now need a pack that can deliver 13.5 amps and a motor *and* prop combination that will draw that much. If I have 10C rated lithium *polymer battery*, then the pack better be at least 1350mAh. *It is* probably *better to* use a 1500mAh pack to be safe.

Using the 80% safe rule for Li-Poly packs, the 13.5 amps should be multiplied by 1.25 (the inverse of 0.8 or 80%). That yields 16.875 amps to be on the safe side. For a 10C rated Li-Poly pack, that would suggest a pack of 1.6875Ah (1688mAh). Rounded up, the closest typical Li-Poly capacity is 1800. To keep the weight down a 15C pack could be used. 16.875 amps / 15C = 1.125AH (1123mAh). This indicates that a 1200mAh 15C pack might be appropriate.

When I look at the chart for the geared Speed 400 I see that, regardless of prop, at 7.4V I am not going to have enough voltage (pressure) to push 13 amps into this motor. The 2-cell lithium *polymer* won't meet my performance goal of 100 watts *in*+ per pound using this gearbox.

If I go back to the charts and look at a different gearbox I *see that I* can't hit my power goals using 7.4V. Maybe we go back to direct drive.
http://www.gwsus.com/english/product/powersystem/edp400.htm

We see that the best I can get this *brushed* Speed 400 to do is a total of 70 watts *in* at 7.2V (close enough), so I can't hit my power goals using a Speed 400 at this voltage, but 70 watts *in* would be about 48 watts *in* per pound. I could have a flyable plane, but not an aerobatic plane using this two-cell pack.

REALITY CHECK!

Now, in fact that is NOT how I would do this. I would decide on the watts *in* target, go to the chart, find a combo that meets my goals, then select a battery that will meet the demand and see if my weight comes up at the target I set. A little tuning and I come up with a workable combo.

I often use the Maxx Products combos for reference. If you read the details on each package they have wonderful information. The fact is that I generally go with brushless motors these days. Costs *for brushless motors* are reasonable and their *somewhat* higher efficiency gives me more performance and longer flight times.
http://www.maxxprod.com/mpi/mpi-264.html

Following the example above, the combo 10 on that page would be an excellent fit for my 1.5 pound plane for sport flying.

The Combo 049 might be a good fit for a slow flyer. Either way the package has all I need.

If I wanted the plane to have all out performance, the 15A or 19A package would be my pick. Note that these would need either higher voltage or higher amperage battery packs. The flyers/PDF for the packages make recommendations.

For those who like to be even more analytical about it, there are packages like MotoCalc *or Drive Calculator (http://www.drivecalc.de/)* that will allow me to play with all sorts of combinations and make suggestions on what I should use. There is a link for MotoCalc below.

SUMMARY

In these few paragraphs you have taken in a basic knowledge of how electric power systems are sized, the factors that are considered and how to predict the outcome. Simple, right?

Of course there is a lot more to know and time and experience will teach you plenty, but with this basic understanding you are better prepared to begin playing with the power systems you put in your planes.

Here are some additional resources that may be helpful.

Brushed Motors (*dead link*)
http://www.hobby-lobby.com/elecmot.htm

Brushless Motors
http://www.hobby-lobby.com/brushless-motors.htm

Brushless outrunners explained
http://www.diynetwork.com/diy/rc_planes_aircraft/article/0,2033,DIY_14224_4320834_02,00.html

Battery Packs - NiMH (*CBP dead link*)
http://www.cheapbatterypacks.com/main.asp?pgid=packs&pid=AIR&sid=445976&ctype=
http://www.hobby-lobby.com/hydride.htm

Battery Packs - LiPo

http://www.cheapbatterypacks.com/main.asp?sid=445976&pgid=tp&sort=PL
http://www.hobby-lobby.com/lithium-polymer.htm

Lithium Balancers and Balancing Chargers
http://www.rcgroups.com/forums/showthread.php?t=599287

Gearboxes - Speed 400 (*link NA)* & 480 examples
http://www.hobby-lobby.com/gear400.htm
http://www.hobby-lobby.com/gear480.htm

A series of posts on electric power system basics
http://www.wattflyer.com/forums/showthread.php?t=1933
http://www.rcgroups.com/forums/showthread.php?t=417868

Maxx Products has a pretty good tip sheet on coming up with a glow to electric power comparison. You can find it here:
http://www.maxxprod.com/mpi/tips3.html

This reader says Keith Shaw originated the watts per pound rule
http://www.rcgroups.com/forums/showpost.php?p=6156600&postcount=39

MotoCalc
This program will tell you everything you need to know: Amps, Volts, Watts, RPM, Thrust, Rate of Climb, and much more! It is a popular tool for predicting the proper motor, prop, and battery pack for electric planes.
http://www.motocalc.com/

This club has some interesting links on their home page that may be helpful in planning props and power systems.
http://www.srcmc.co.uk/

Drive Calculator Version 2.21 (*no longer available*)
Was based *on* a Microsoft Excel spreadsheet

Drive Calculator for Windows, Mac and Linux
http://www.drivecalc.de/

The Great Electric Motor Test
http://www.flyingmodels.org/motortest/index_e.htm
This data is old. The motors, while still having the same designation have changed. Some of the props, while still having the same designation, have been redesigned. Both of these make the numbers quite unreliable today.

Prop Versus Amps

With a given prop, your electric motor draws a certain amount of energy to do its job, which is to turn the propeller. With no prop attached it draws very little energy. If you put a "big" prop on the motor it draws a lot of energy.

This is similar to pulling a boat trailer behind your car. The car might get 20 mpg normally, but put a boat on a trailer behind the car and mileage will drop off to perhaps 15 mpg because the *engine* is using more energy just to maintain the same speed and travel the same distance. However as long as the boat and trailer are not too heavy, no real damage occurs, you just use more gas.

If you put too big *of* a trailer behind your car, something will break. The *engine* may fail, the transmission may fail or something else. That is because you are asking the drive train to produce more work *and* use more energy then it was built to handle. Fuel mileage goes way down and then something breaks. You have over stressed things.

Back to your plane.

Your electric motor *draws* a certain amount of energy in order to turn a given propeller at a given speed. Let's use a brushed Speed 400 motor as an example and let's say you have a 6x5 prop on it. That means the propeller is 6" *in diameter* and has a pitch of 5" per revolution. Pitch indicates how far the prop would move forward through the air if there were no slippage. As either of these numbers go up, the motor is asked to do more work.

Now let's apply some numbers. <u>These are made up numbers for illustration only.</u> Don't assume that these are accurate for your motor in your plane turning your prop.

Let's say that, to turn that 6x5 prop your Speed 400 motor draws 6 amps using a battery that delivers 10 volts, just to make the math simple. That would be 60 <u>watts *in*</u> of energy that the *power system* consumes to turn that prop. (6 amps *times* 10 Volts)

If we go to a larger prop, say 7 inches and keep the pitch the same *at* 5 inches, the draw might go up to 8 amps at 10 volts or 80 <u>watts *in*</u>.

Likewise if we went to a 7x6 prop, the draw would go up again, say to 9 amps or 90 watts *in*.

In each case we are increasing the amount of work the motor has to do to turn the prop. The harder it works, the more electricity it draws. This is also placing an increasing amount of stress on the motor causing it to generate heat and placing more pressure on the bearings. If we push it too far, the motor will be unable to turn the prop fast enough to be useful *for* flying the plane and/or *the motor* will fail from stress, just like the car example above with the trailer that is too big.

What we try to do is to get the best balance of propeller and amp draw so that the motor operates efficiently without being overstressed.

Likewise if you have that same Speed 400 motor and keep the prop at 6x5 but increase the electric pressure, volts, to 12 volts it will *allow the motor to pull more amps*. This would be like putting a supercharger on your car's *engine* which forces more fuel *and* air mix into the car's engine. It will produce more power so it can do more work. However, if we exceed the amount of power it was designed to handle, it will fail. It might not fail right away, but over a very short time it will start to degrade, perform badly and perhaps suddenly fail all together.

If we push the voltage up too high or the amp draw too high, we will overstress the motor and damage it.

The goal is get a good balance of propeller and power draw.

OTHER RESOURCES

A comparison of Glow vs. Electric power
http://www.maxxprod.com/mpi/tips3.html

Electric Motors Described
http://adamone.rchomepage.com/guide5.htm

MotoCalc
MotoCalc will tell you everything you need to know: Amps, Volts, Watts, RPM, Thrust, Rate of Climb, and much more! It is a popular tool for predicting the proper motor, prop, and battery pack for electric planes.
http://www.motocalc.com/
The Great Electric Motor Test (*outdated data, both the props and motors have changed)*
http://www.flyingmodels.org/motortest/index_e.htm

Why Consider a Gearbox?

We are going to discuss why we would consider adding a gearbox to a brushed electric motor.

I am going to get rea*lly* loose with the words "gear ratio" for a moment, but try to follow me. Think of gear and gear ratio as the way we adjust the load on the motor. I can adjust the "gear ratio" on my motor *and* propeller set-up in one of two ways:

1) change the propeller
2) add a gearbox and change the propeller

The goal is to get the motor spinning, at full power, at its optimum watt range so that we do not over burden it, but so that we get the power to the propeller efficiently. We are trying to get the best balance between pitch speed, thrust and current draw.

If I increase the diameter of the propeller while holding the pitch constant I put a greater load on the motor. A 10x6 prop puts a greater load on the motor than a 9x6 prop. It will cause the motor to draw more power, more amps. At the same time, it may load it enough that it causes it to slow down. Its peak RPM may well be less. This is similar to changing gear ratios on your bicycle. You can feel the effect in your legs.

If I deepen the pitch on the propeller while holding the diameter constant, I also increase the load on the motor. *For example, going from a* 9x6 to a 9x7 to a 9x8 *increases the pitch*. In this case I am increasing the "pitch speed". Again, this is similar to changing the gear ratio. As I go to a deeper pitch, the current draw will increase, the watts *in* increase*s* and we may again load the motor enough to decrease its top RPM.

If I go *to too large of a diameter*, or too deep *of a pitch*, I can overload the motor and burn it out.

On a direct drive set-up, no gearbox, I tune my propeller *using* pitch and diameter to get the motor to the power range I want. Again, this is EXACTLY the same as changing gear ratios, in practical application.

To some extent I can trade pitch for diameter and vice versa. You will see motors listed as accepting a range of propellers. Typically as diameter goes up, pitch goes down.

9x7
10x6
11x5

For this sample motor, each of these props will probably produce a similar watt *input and* output but they do it with different results.

The *larger diameter* prop will provide more thrust but the lower pitch will produce less speed. I can tune for the application. Sailplanes typically want more thrust for steeper climb but are not as concerned about speed. Pylon racers are less concerned about climb or acceleration as they are about top speed. Hopefully you get the idea. I am tuning the "gear ratio" by changing the prop.

If you are not with me up *until* now, then ask, because what comes next depends on your understanding what is above.

ADD A GEARBOX

Now, suppose I have a given motor, say a brushed 550, and my prop choices don't give me the thrust I want to take my 2-meter sailplane up at a steep enough angle to make me happy. It takes too long to get to *get to* soaring height. Or, suppose I want to fly a larger, heavier plane with the motor I have. My prop choices don't give me enough thrust to handle the heavier plane. What do I do?

I can put a gearbox *on the motor*. The gearbox will have two effects. It will reduce the top speed to the prop, but it will increase the torque available to turn the propeller. This allows me to go to a *larger diameter* propeller but my top speed will be reduced. Now I can get a steeper climb, or perhaps I can fly a larger or heavier plane.

I am going to stay with the sailplane for the rest of the discussion, but it applies equally to any kind of aircraft. We are talking gear ratios.

Again, using the bicycle example, you shift to a lower gear to go up the hill. You can get up the hill in first but if you were to go to third you might not have enough power in your legs to turn the pedals. You tune the gear ratio to match the available power.

A typical prop on a 550 motor in a sailplane, like a Goldberg Electra, would be an 8x4. That is the *largest diameter* prop, the highest thrust prop that this motor can comfortably turn and provide enough speed to fly the glider. The motor will likely pull about 18 amps on an 8.4V pack. It will fly the plane, but the climb angle might only be about 25 degrees. It might take me 2 minutes to fly up *to* the height I want to reach. This plane isn't really made for speed, so going to a 7x6 prop, trying to get more speed, won't help.

If I put a gearbox on, say a 3:1 ratio, I can go to an 11x8 or a 12x7 prop. Now I get a lot more thrust and the plane will climb at a 50-degree angle. Now I get to height in less than a minute and the motor might only be pulling 16 amps. I climb in less time AND I may be *requiring* fewer <u>watts *in*</u> to do it.

That is why we go to a gearbox. Usually it is to allow us to swing a *larger diameter* prop at a slower speed in order to get more thrust at the sacrifice of speed.

WHAT ABOUT BRUSHLESS INRUNNER VS OUTRUNNER?

Because we have two motor types in the brushless world we add flexibility and complexity. More choices mean more to decide.

The gearbox discussion with a brushless inrunner is exactly the same as for the brushed motor above, so I won't repeat it.

However if we look at *brushless* outrunners *versus* inrunners we see that outrunners tend to spin slower *at a given* volt*age* with more torque. This has a similar effect to having a gearbox on an inrunner. How do you decide?

1) Personal Preference
2) Mounting restrictions
3) Available motor choices

Some people don't like gearboxes. *To them* it is another thing to maintain and another thing to break. Also, gearboxes tend to make noise and some people don't like that. However there is nothing spinning around inside the plane with a gearbox. You can mount the motor *with its* gearbox without regard to clearance as long as you have adequate air flow. You can just clamp a gearbox *attached to an* inrunner to the frame of the plane and you are done. I have seen *the* motor *and* gearboxe~~s~~ left loose in the nose of the plane. The Multiplex Easy Glider is set-up this way. No mount at all, it just sits there.

Outrunners need space. You have a spinning can that must be protected from contacting another surface, loose parts, wires, etc. Grass, string, *and other* stuff can get caught on that spinning can. In some cases this could be a problem, so a gearbox might be preferred.

I have read that brushless inrunners are typically more efficient than outrunners, even with the gearbox losses. If that is true, and if that matters, it could shape your decisions.

Summary

We can tune our power system by adjusting the "gear ratio". Changing props to some degree can do this. After that we go to gearbox systems to tune our power systems to give us the performance we want.

What Do the Kv Ratings On Motors Mean?

Manufacturers use different wire winds to produce different Kv results.

In simple terms, the Kv is a number that relates to how many RPM a given motor*, with no load on it,* will spin based on *the* applied voltage. You will see specifications on motors where it says Kv=860. That means that the *unloaded* motor will spin at 860 rpm if you apply one volt to it. If you apply 7 volts *to the unloaded 860Kv motor* it will span at 6020 rpm. *(7V times 860Kv)*

If the manufacturer takes the same motor he can wind it *with more winds of thinner wire* so that it will have a lower Kv rating, which typically produces more torque. These are typically used with large propellers that will be turned slower. These are very popular on gliders, for example, where climb angle and climb rate is much more important than top speed.

Take the same motor and wind it differently *with fewer winds of larger diameter wire* and it will have a higher Kv rating producing higher speeds for a given voltage. These are typically used with smaller props for higher top speeds. They can *also* be used with gearboxes to handle those big props, providing a similar result to low Kv motors. Sometimes a gearbox works better in the installation.

You would also take Kv into consideration based on what battery you plan to use.

If you look here (http://www.maxxprod.com/mpi/mpi-262.html) you will see that a given motor is offered in several Kv ratings. They make suggestions as to which motor is best matched with which prop and which battery packs. If you click on a given motor you can see *how much* power is drawn based on which pack and which prop. If you click on each of the motors within a model you can see the very different power curves produced by the different battery *and* prop combinations. Here you see the same motor with different wind*s* producing a different Kv result, each optimized for a different purpose.

How does this add to other information about motors?

I first set a watts *per* pound target for my plane, depending on the performance I want. I typically target between 70 and 100 watts *in* per pound for sport planes and gliders. I don't fly 3D.

Then I consider whether I am looking for high speed or high climb rate. A glider or a 3D plane would be optimized more toward the climb rate side of this discussion. A pylon racer would be optimized more for speed. A pattern *or sport aerobatic* plane might be somewhere in the middle.

Now I get down to *the* prop and battery. *A l*arger diameter prop *is used* for better climb *and smaller diameter, higher pitched* prop for higher speed. Now look at the motor character*istics* based on either battery target or prop target and choose the motor/battery/prop combination that meets *my* objectives.

That is kind of high level but you get the idea.

Who Needs a Wattmeter/*Power Meter*?
A personal experience reveals their value.

I enjoy electric planes. They are quiet, convenient, can be fast or slow and are fairly inexpensive to fly.

A few months back I picked up a Watts-up wattmeter/*power meter*. http://www2.towerhobbies.com/cgi-bin/wti0001p?&I=LXLMV0&P=ML

I thought it would be a good investment, as I was doing more in the area of mixing and matching motors, props, and the like. It is small and simple to use, so I put it in my field box. It wasn't long before it started to show its value.

We were flying one afternoon when one of the club members felt he was not getting good performance from a new plane *that* he had built. I put the wattmeter/*power meter* on the plane and determined he was pulling about 9 amps. *It* turned out *that* the pack he was using really was not up to the load and the voltage was dropping off excessively. As a result, he was not getting the RPM out of the prop that he expected. The problem *was* discovered and *the* cause identified in a few seconds *using a power meter*. He needed stronger battery packs.

A few weeks later we did the same thing with another plane. There was a concern that the Li-Poly being used might be getting over worked. However the Wattmeter showed that it was working well within its rated capacity. Flying went on with confidence.

I recently purchased an Easy Glider Electric from another club member. He had upgraded the motor from the stock *brushed* Speed 400 to a brushless *motor with* a 27-amp ESC and was using a 2 cell 2100mAh Li-Poly. I bought the whole package.

The plane flies very nicely on the 2-cell pack, but I had a 3-cell pack that I thought *that* I might add *in*to the rotation and REALLY boost the power. The ESC could handle a 3-cell Li-Poly, so I did not see a problem. I assumed the system was probably running at about 18 amps, which was within the rating of this pack. *It* should be a good fit.

Fortunately, before I tried it in the plane, I put the wattmeter/*power meter* on the system. I was surprised to see that the system was *drawing* 26 amps on the 2-cell Li-Poly pack. That was much higher than I had expected. It turned out that the 2-cell packs were an excellent match for the motor and speed control. The amp load was well within the specifications of the 2-cell packs being used and the plane flew very nicely on this combo.

If I had blindly put a 3-cell pack in there I would have pushed *the system* well past the ESC's 27 amp rating and probably burned out the speed controller. Or, in the case of my 3-cell pack, it would probably have pushed over 30 amps into the system due to the higher voltage, but *the pack* was not rated for that high of an amperage *draw* and would probably have had a short life working at that level. I would have thought it was just a crummy battery pack, but in fact I would have been overworking it.

Operating in the blind, I would have ruined the ESC, or the pack, or both. *It would have been* a very expensive mistake, certainly more *expensive* than the cost of the wattmeter/*power meter*. It had just paid for itself.

A few days ago I pulled out my old Electrajet to prepare to sell it. I had purchased it almost 3 years ago, but had never really been happy with the plane. My interests have turned more toward gliders and slow flyers rather than a pusher jet. When I purchased it, I also bought some *NiMH* cells and made up some 8-cell packs. However it really didn't seem to have the zip I thought it should. I just attributed it to the *brushed* Speed 400 motor and the plane being too heavy.

I put the wattmeter/*power meter* on the motor *and* battery combination. The motor sounded about as I had recalled. When I checked the meter, low and behold, those 8-cell packs were duds! They were 9.6V 8-cell 1000mAh packs rated for 10C. At rest, fresh off the charger, they were reading 11 volts, but when I hooked them up, they were both dropping to 7 volts while delivering 9 amps. That is way too much drop! The problem was not the plane or the weight of the plane but the quality of the cells I had used.

I tried one of my 15C Li-Poly packs and that held voltage well, delivering 13 amps. The motor screamed! Now that was more like what I had expected. Hummm, maybe I won't sell it after all. I just need to put better battery packs in it.

I also tried a 1000mAh 2-cell lithium pack that is rated at 10C. The voltage sagged to 6.6 volts almost immediately. The motor ran, but I was clearly over stressing the pack. This pack would have been ruined in very few flights if I had used it to fly the plane regularly.

I share this story only to help you understand that, without a wattmeter/*power meter*, or the use of a multimeter with knowledge and skill, we are working in the blind. We really don't know what is happening in our power systems.

Who *Really* Needs a Wattmeter/Power Meter?

While the wattmeter/*power meter* is *truly essential* to have, *only a very few* people *might not need* one. If you are buying RTF planes, or ARF or kit planes and are using the manufacturer's supplied motor and battery packs, I would say *that* you could be pretty confident that all is well.

However, if you start mixing and matching motors, gearboxes, props, controllers, battery packs and the like, you are really working in the blind if you are not measuring the energy flow in the system. In my case, I started making my own battery packs, but I was not measuring their performance. Now I know the true results.

There are a variety of wattmeter/*power meters* out there. This one is easy to use and fits nicely in my field box, but there are other good ones. If you are going to upgrade your power systems or make up your own packs, you need a wattmeter/*power meter*. You can perform many of the same tests with a millimeter, if you know how to work with shunts and the like, but if you want a simple to use tool that does exactly what you need it to do, this is hard to beat. It has other uses too, so read the instructions, but for this use alone it *has* paid for itself pretty quickly.

Sources:

RC Electronics Watt's Up
http://www3.towerhobbies.com/cgi-bin/wti0001p?&I=LXLMV0&P=ML

Astro Flight Super Whatt-Meter
http://www3.towerhobbies.com/cgi-bin/wti0001p?&I=LX3605&P=7

Doohan DC Watt Meter
http://www.bphobbies.com/view.asp?id=A0320107

Feigao Power Analyzer
http://www.bphobbies.com/view.asp?id=A0320107

Power Meter by E-flite
http://www.horizonhobby.com/Products/Default.aspx?ProdID=EFLA110

Hyperion Emeter Version 2
http://www.allerc.com/product_info.php?products_id=4322