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## **Electric Power Plant Selection Guidelines**

**By Sam Brauer**

Choosing the power plant for your new creation is one of the keys between success and failure. The correct choices can allow your new plane to have the performance you desire- an incorrect choice can result in either a powered glide to the ground or "sleddus nicaddus"- an overweight aircraft which is challenging, but not necessarily very rewarding to fly.

There are three major components in an electric flight power system- the battery, the propeller, and the motor/gearbox. The power system is only as good as its weakest link, therefore, for optimum performance, all components play a critical role.

In the design process of matching a power system to an aircraft, one of the best ways to proceed is to determine the projected all up weight of the aircraft, determine the watts needed, the propeller (or fan) and finally the motor. Iterating the process until you come up with a solution that hangs together is one of the fun challenges in e-flight.

There are 3 pieces of information you need to determine what battery (group of cells) to use in a particular airplane:

- 1) The number of watts needed.
- 2) The weight of the battery
- 3) The size of the battery.

There are a variety of rules of thumb out there. For most reasonably aerobatic sport aircraft applications- it's not very hard- start at 100 watts/lb (when measured hot off the charger, i.e. within the first few seconds of a running.) This will give performance comparable to glow powered aircraft. Slower aircraft can get away with fewer watts/lb, faster aircraft may need more. Old style pattern type performance probably needs closer to 125-150 watts/lb- race airplanes- you're on your own.

Obviously- figuring out your total watt requirements is something of an iterative process- starting with your empty weight, you get to add in the weight of the batteries and everything else to get to your total weight. I typically figure battery weight between 25-35% of an airplane's gross weight.

Nearly all e-planes will require a battery made up of two or more cells (light indoor stuff is an exception.) This FAQ is intended to help you choose what cells to use to make up your airborne battery.

At this point in time (November 2002) there are 5 broad classes of cell types that can be used in e-flight. I suspect that this FAQ will become rapidly dated, battery technology has been changing quickly over the past decade, and this rate of change shows little signs of abatement. While other areas of e-flight (motors, escs, radios) etc. have reached some level of maturity, battery cell technology continues to evolve. It is quite possible that fuel cells will render all our current technology obsolete in less than a decade.

As noted above, the first question we need to answer when choosing a battery pack for an airplane is: how many watts do we need? This is where the 5 broad classes of battery cell types come in. Recall that watts are simply amps x volts. In terms of battery cells, the weight of the cell is related to the number of amps it can deliver- larger and heavier cells can deliver more amps, and hence, more watts. The 5 classes of cells are:

- 1) Less than 8 amps (generally found in airplanes less than 1 lb.)
- 2) Between 10-15 amps (generally found in airplanes from 1 lb to 1.5 lb)
- 3) Between 22-28 amps (generally found in airplanes from 1.5-2.0 lbs)
- 4) Between 30-40 amps (generally found in airplanes 2 lbs plus)
- 5) Between 35-45 amps (generally found in airplanes 2.5 lbs plus)

This all seems so simple doesn't it? Where lots of aspiring e-pilots run into trouble is that battery manufacturers don't label their cells in this fashion. Well, why not? In e-flight, we abuse batteries, we don't use them within the operating parameters specified by the manufacturer. Battery manufacturers sell batteries on the basis of capacity first and foremost. Unfortunately, battery capacity changes as a function of discharge rates- higher discharge rates will yield lower capacity. Consequently, battery manufacturers don't label their cells as a 10 amp cell for example, they label cells as having 1020 mAH. For e-flight purposes, we really need to identify the amp delivery capabilities of a cell, much more than its capacity, so the manufacturers rated capacity becomes an arbitrary designation for a cell. Further complicating the issue- one manufacturers 1700 mAH cell will deliver up to 15 amps, another manufacturers cell will handle 25 amps, and yet another cell will handle 40 amps. Consequently, you need to be careful to identify a cell with information other than capacity- often sizing codes are used. This doesn't make things easier for the e-flier, but that's the way the battery industry operates. Since we are not a significant market to these manufacturers, they're not going to listen to our requests, so this becomes something that we all must learn to deal with. (Battery mfg aside- there is only one battery mfg which has devoted significant resources to e-flight- SR Batteries,) which manufactures both cells and assembles packs. SR cells for e-flight are conveniently labelled Max cells and come in sizes which roughly correspond to the classes below. Some of the newer li-poly mfg such as Kokam and Thunder Power are also devoting some resources, but neither of these firms has the track record of SR.)

Battery Chemistry- there has been a great deal written about the type of chemistry a cell uses to deliver its voltage. Let me point out that the airplane does not know whether it has a nickel cadmium (nicad), a nickel metal hydride (NiMH) or a lithium ion polymer (li-poly) cell inside. We'll cover the advantages and disadvantages of each down below, but getting the correct amount of watts and weight is far more important than which

battery chemistry to choose. (Environmental Aside- one of the attractions of e-flight is its non-polluting nature. It should be pointed out that all batteries are not alike in terms of environmental considerations. Nicads, which contain cadmium- a toxic heavy metal- are far and away the most harmful to the environment and need to be disposed of carefully. Radio Shack is serving as a collection point for discarded nicads. NiMH cells are much less problematic, and Li-polys even less so. Li-polys can apparently be discarded with normal household trash, I'm uncertain as to the status of NiMHs.)

About amp delivery- most sources estimate the amp delivery of a cell as where it will still deliver close to its rated voltage. As the amount of amps drawn out of a cell increases, the voltage the cell produces drops. Since amp delivery can increase faster than voltage depression, fliers interested in maximum performance strive to use higher amp systems- as exemplified by F5B competitors who exceed 100 amp draws from their batteries. For sport fliers however, the rated amp delivery of a cell is often set at where the cells voltage hits 1.0V for either nicad or NiMH, or 3.7V for Li-poly (a safer alternative is to use 3-5 x rated capacity of the cell, C frequently written as 3-5C. This technology is evolving rapidly- there are already some cells which are rated at 5C continuous draws, and 10C for short time periods.) In e-flight, there are 3 questions to ask about a cell-

- 1) How many amps can it deliver?
- 2) What does it weigh (and how large is it if battery space is limited)
- 3) For how long will it deliver this amperage? (Duration- often the bugaboo of e-flight.)

While the first two questions are straightforward, the last one is not. Since rated capacity falls as amperage draws increase, we should not expect to get the manufacturers rated capacity of a cell under e-flight demands. The difference between the rated capacity and the actual capacity depends upon the usage of the cell. One thing to be careful of is that a cell which has a high rated capacity, when used under e-flight amperage loads, can fall dramatically. As an example, a CP 1300 mAH cell will deliver about the same amount of mAH as a 1700 mAH 4/5 AUP cell when used at amp draws exceeding 25 amps. Cells which have high capacities, but relatively low amp delivery characteristics will only be good for low powered duration applications.

## Battery Chemistry General

Here are some guidelines which describe the overall characteristics of cells based on users experience.

Nicads-often the highest energy output of any cell, robust, well proven technology. Easy and fast to charge. Moderate temperature dependence. (Memory is nonsense in R/C applications.) Disadvantages- in most applications, the lowest duration of any cell type.

NiMH-some newer NiMH cells offer energy output comparable to nicad at reasonable amp draws. For higher amp draw applications, most nicads are superior. (Exception- largest NiMH cells may outperform nicads.) Disadvantages- strong temperature dependence- NiMH cells like to be warm. NiMH cells also lose charge rapidly, best to charge immediately before flying. NiMH cells will generally not tolerate abuse as well

as nicads- more sensitive charging technology needed- total number of cycles less than nicads.

Li-poly- can offer very high energy output and capacity. Low temperature dependence, plus excellent charge retention. Disadvantages- limited availability, slow charge rates, delicate. Still experimental in applications, thus longevity is unknown.

One of the most common mistakes in e-flight is to use a cell larger than needed. There are two ways to improve performance in a given airframe- add lightness, or add power. If your cells are heavier than needed for a given amp draw, you've violated tenet 1), i.e. add lightness. Always be very careful when using a cell larger than needed in an application- it's the quickest way to "sleddus nicaddus".

Now that we've got some of the basics under our belt, let's get to some more specific guidelines. Please note that these are guidelines- not the ten commandments. I'm sure that there are exceptions to every rule, but these guidelines are intended to get your thought processes moving in a direction which has been successful for lots of airplanes. If you find that your coming up with a power system which is very far away from these guidelines- be careful, odds are there's a problem somewhere. Also note that these guidelines are not intended for competition purposes- they're intended for the average "sport" flier.

This guideline also separates cells into classes. There are advantages and disadvantages to this approach. The advantages are that we get to compare various types of cells for similar applications, i.e. an apples to apples comparison. It does very little good to compare a lithium polymer cell which is suitable to a parkflier to a CP 2400 nicad cell which is utilized in 4 pound plus sport aircraft. The disadvantages are that these classes are not recognized outside these guidelines, so if you go to a hobby dealer, and say "I need a class 1 cell." He's liable to look at you oddly and sidle carefully towards a phone. On the other hand, if you can describe what characteristics a class 1 cell has, i.e. battery packs less than 5 ounces- used in under 8 amp draw applications, then you have a fighting prayer.

#### Class 1 cells (under 8 amps)

These are the cells which are used indoors and in parkfliers with total watt applications at 60 watts or less. Aircraft which use these cells can be up to 20 oz. or so. Battery packs in this class typically weigh under 5 ounces and range from 2 to 10 cells.

This area of e-flight has seen a revolution in the past year. Effectively Li-poly technology has taken over the indoor scene, and is now rapidly making inroads into parkfliers. This class of cell has more types of cell chemistry represented than any other with: nicad, NiMH, Li-ion, Li-poly, and Li-Mn (Tadiran, fading from the scene- no longer available.) Consequently, there is a big shake up going on with motors and aircraft as well, since motors must match the characteristics of the battery.

Li-poly's have a dramatic advantage in this size range since they don't have a metal case. Consequently, they have a big weight advantage over all other forms of battery technology. Li-poly cells are available in capacities from 50 mAH to 2070 mAH, with more capacities being added on a fairly regular basis. Li-poly's have wonderful energy density in this class of cells, with Li-polys being able to deliver more amps, at lighter weight and for longer than other battery technologies. These cells are not as temperature sensitive as other cell chemistries, plus they retain their charge without loss for extended periods of time. (No need to top up right before flying if charged the week before.)

Other properties- Li-poly cells deliver 4.2V without a load, which drops to 3.7V under load. Consequently, a 2 cell Li-poly battery will deliver 7.4V under load- which makes it roughly comparable to a 7 cell nicad or an 8 cell NiMH. At this time, 2 cell configurations are very popular, but 3 cell batteries should also prove to be a good match with motors which perform best under high voltage/low amperage situations (ex. Astro 010, Speed 280). These cells are limited to 3-5C in terms of amp delivery.

Disadvantages- motors which perform best on less than 7V, i.e. HY-50F, MG-1, HY-50D are poor matches for these cells. Also, pack assembly appears to be a tricky business, and these cells are not as robust as other cell types. These cells are still experimental, and longevity remains an unknown.

Cost- since these cells are being used in consumer applications, costs of smaller cells is falling rapidly. Already a 2 cell pack of 1020 Li-poly cells is cost competitive with NiMH or nicad.

Li-ion- these cells use similar chemistry to Li-poly, but wrapped in a cylindrical metal jacket. Consequently, the weight of these cells is higher than Li-poly for a given amp delivery. In terms of performance- these cells have excellent duration, but do not deliver more amps than nicad at a given weight. Again, used in consumer applications, so cost is highly competitive.

Nicad-For many years the performance standard in battery technology. In this size range, nicads will deliver more amps per ounce than NiMHs, however, nicads do so at the expense of duration.

NiMHs- still do not have the amp delivery of nicads in this size range- consequently it is necessary to add an extra cell as shown in the example below. NiMHs also have a strong temperature dependence- these cells should be warm when used. Furthermore, NiMHs also lose charge the quickest of any cell- topping off before flying is highly recommended.

Example- M-100 motor with stock prop

Typically draws about 4-4.5 amps with stock prop at 7.4V

Battery options-

a) 2 cell Li-poly-1020 mAH wt. 1.5 oz.

- b) 7 cell nicad 350 mAH wt. 3 oz.
- c) 8 cell NiMH 720 mAH wt. 3.4 oz.

Most widely used cells- below 8 oz airplanes- 8 cell 300 mAH NiMH, above 10 oz- 8 cell 720 mAH NiMH.

## Class 2

Cells from 10-15 amps. Typical battery packs weigh from 5-8 oz. Aircraft which used these cells range from 16 oz to 28 oz. Typical watt range from 75-150 watts from 7-10 cells.

There are two popular types of cells, the 600 mAH AE nicad, and the 1100 mAH NiMH cell manufactured by HE cells (plus Hobby People equivalent- which may be the same cell in a different wrapper.) Li-polys are poised to make an impact in this class of cells, but to date, their impact has been minimal.

The 600 AE nicad has been a staple of the Speed 400 class of airplanes for years. This cell weighs about 0.6 ounces, and will deliver up to 12 amps- occasionally more if pushed.

The 1100 HE cell is much newer. This NiMH technology delivers basically the same watts per cell as nicads, thus an 8 cell pack of HE cells is roughly equal in power to the 600 AE. The cell may be able to handle somewhat higher amp draws as well- some users have reported good results at 15 amps, which is somewhat better than 600 AE cells. Duration is much improved compared to 600 AE cells, reports range from 33-50% increases. Note that when pushed to deliver more amps than 600 AE, cell deteriorates rapidly.

Other options- 1100 AAU nicad. Somewhat heavier than 600 AE, delivers more watts however. Cell is somewhat delicate for a nicad, well suited for duration applications.

1350 NiMH cells- slightly heavier than 1100 HE cells. Performance comparison data lacking.

950 KAN cells. NiMH cells- reported to deliver more volts than either the 600 AE or 1100 HE Cell when used very, very warm. Possibly more robust than HE cell.

Older NiMH cells, such as the 1050 mAH cells should be used with caution- these cells do not deliver the watts of a 600 AE and should be used in lower amp draw applications.

## Example

Speed 400 on a 5.5 x 4.5 prop draws about 12 amps on 7 volts. Battery options, 7 cell 600 AE, 7 cell HE cell 1100, 7 cell 1100 AAU, 7 cell 1350 NiMH.

### Class 3 Cells

Class 3 cells are a large jump in weight over the class 2 cells. On average, these cells weigh about 1.2 oz. or double the weight of class 2 cells. However, these cells will also deliver 25 and occasionally 30 amps, which means that they deliver double the power as well. These cells work best between 20 and 28 amp draws however. These cells can be used in airplanes from 24 oz to 48 oz. and can deliver from 150 to 275 watts. Typically class 3 packs range from 7 (for a 6 cell pack) to 14 oz and packs run from 7 to 10 cells (6 cell packs are somewhat uncommon, but can be useful.)

There are really only two choices at this amp draw- the CP 1300 nicad, or the 4/5 AUP 1700 mAH NiMH cell. Both cells function well at 25 amps or below, the CP 1300 may have a slight performance advantage at higher amp draws. The 4/5 AUP NiMH cell does have a significant duration advantage when used below 25 amps.

Example- Jeti 15-4, 8.5 x 6 prop, 8 cell 4/5 AUP 1700 NiMH battery- 8 V at 25 amps- 200 watts.

Common Problems- one of the most common misuses of batteries in e-flight concerns these cells. Many people desiring more power for a parkflier using an 8 cell 600 AE pack will substitute a 7 cell CP 1300 pack or 8 cell CP 1300 pack. They will complain that the added power does not make up for the additional weight. Realistically, a significant power increase from an 8 cell 600 AE pack is either a 9 or 10 cell pack, or a 6 cell CP 1300 or 4/5 AUP pack. Clearly, this entails changes in prop and gearing, and rarely will a motor be happy under these conditions. In general, these batteries do not belong in airplanes which fly acceptably on 8 cell 600 AE packs.

### Class 4 Batteries

Class 4 cells offer a 1/3rd increase in amp draw up to 40 amps at the expense of a 25% weight increase. Typically, these cells can be used in applications from 250 watts to 650 watts with 8 to 16 cells in a battery. There are three types of cells in this class, the CP 1700 nicad (most popular) the 4/5 FAUP 1950 NiMH cell (not widely available yet) and the 2000 mAH NiMH cell (older technology and fading from the scene.) Aircraft which use these cells can range from 2 ¼ lbs to 7-8 lbs (or larger)

These cells are very versatile and can be used in relatively small aircraft, to some of the larger sport e-powered aircraft. These cells offer a significant performance boost over Class 3 cells around 28 amps or so, and will function up to 40 amps.

The CP 1700 remains the most popular cell in this class. Compared to the older technology 2000 NiMH cell it offers significantly higher watt delivery per ounce over 25 amps. The older technology 2000 mAH NiMH cell does have a duration advantage however, when used at 25 amps or below. There is too little data to compare how well the 4/5 FAUP cell will function when used at higher amp draw levels.

Example- Jeti 30/3 on 12 cell CP 1700, 9.5 x 7 prop, 12 V at 42 amps- 500 watts.

In most cases, the 10 cell CP 1700 has proved to be a better choice than the 8 cell CP 2400.

### Class 5 Batteries

These are the largest cells commonly used in E-flight- typically weighing between 2.1 and 2.3 oz. However, most applications for these cells limit amp draws to between 35 and 45 amps. Consequently, aircraft powered with these cells do not necessarily have a performance advantage over class 4 cells, although they generally have a duration advantage. Class 5 cells come as either nicad or NiMH technology, and the difference between the two can be hotly debated. These cells should be used in applications from 350 watts to 1000 watts- in aircraft of 4 lbs to 12 lbs. Batteries consist of 10 to 24 cells (occasionally more).

There are several cell types available- two nicad- the RC 2400 and the CP 2400, as well as several NiMH cells, 2600, 3000, 3300 mAH cells, also available in high voltage (really high amperage) varieties. In this class size, NiMH cells have comparable wattage output to nicad, thus a 16 cell NiMH pack is comparable to a 16 cell nicad pack. All of these cells have their adherents and meaningful comparisons are difficult. Realistically, the CP 2400 still offers an excellent blend of performance and low cost.

### Common Problems

All too often, relatively new e-flyers will want to use these cells at 25 amps or so. In general, this is a mistake. At that low an amp draw, some smaller and lighter NiMH cells will provide excellent duration at good weight savings. These cells should not be used below 35 amps or so, in order to avoid “sleddus nicaddus.”

### A note about cell counts-

As noted earlier in this FAQ, for a given number of watts, a higher voltage setup will prove to be more efficient than a lower voltage setup. This should favor higher cell counts in larger aircraft. You may note that a lot of aircraft stop at 16 cells though. This has more to do with ESC technology than batteries or motors. ESCs that can handle 20 plus cells have much heftier price tags than ESCs limited to 16 cells. In many cases though, a higher number of smaller cells could deliver better performance than a fewer number of larger cells, as long as both cells are used at reasonable amp limits.

### Propeller Selections

One of the most common mistakes in e-flight is to use the same propeller that you would use on a glow powered model. Most of the time, this is an error- occasionally a bad one. The reason is that most glow powered aircraft use propellers sized for the engine, not the

airframe, and there are often terrible mismatches. These mismatches are a loss of efficiency- not such a problem when you have a very powerful lightweight powerplant, but when you are using a somewhat heavier or less powerful powerplant- you need to be careful about throwing away energy. This added increase in propeller efficiency is why electric airplanes can fly comparably to glow powered models on less input power.

Realistically, you need to size the propeller to the model without using some preconceived notions. Full scale aircraft occasionally have propellers that are up to 1/3<sup>rd</sup> the wingspan- check out the props on WWII fighters for example. Other constraints such as landing gear, or other clearances need to be looked at. You want to use the largest propeller that can comfortably fit on your airframe- with one codacil- pitch speed.

Pitch speed is how fast the propeller would move through the air if there would be no airplane attached. We generally assume that a slick airframe can actually get pretty close to this theoretical pitch speed, but a draggy airframe cannot. Pitch speed is calculated by multiplying rpm x the pitch in inches. (No the units don't work- it's a complete kludge- but it turns out close enough.) As an example- a propeller with a 6 in pitch turning 10,000 rpm has a pitch speed of 60 mph.

Nicely performing aircraft have a pitch speed which is 2.5x stall speed. Most sport models in the 4-8 lb range stall around 20 mph, so a pitch speed of 50 mph is a good minimum for a high wing sport scale/trainer type airplane- closer to 60 mph for an aerobat or warbird, and 70 plus mph for old style pattern.

As an example of prop sizing- I went from a 9 x 5 on a K + B 28 (no tach) on a 500 sq in Corbin Super Ace (1930s high wing lightplane) to a 12 x 8 E prop turning about 6500 rpm. The electric version is slower, not as maneuverable, but flies in a more scale like manner- and has far better climb at low airspeeds. The larger prop has the ability to pull the airplane out of trouble.

I've also used comparably sized props on electric versions of airplanes originally powered by glow. In general, the electric versions are a bit slower, and lack some of the vertical performance of the glow powered versions. However, if you go to a larger prop, you will not regain the missing airspeed (larger props have lower pitch speeds) but you will regain or conceivably surpass the glow powered versions vertical capability.

#### Motor/Gearboxes/ESC

I've left the selection of motors till the end, because with electrics, I find it's more critical to know watts and propellers before looking at motors/ESCs and gearboxes. Of course motor mfg would rather have you pick their motor first, which may help explain some pretty funky battery recommendations coming from them.

There are several types of motors in the market today- ferrite (cheapest), cobalt (fading from the scene) and brushless (often my recommendation). It's important to realize that most of the time, what you're paying extra money for in a snazzier motor isn't more

power- it's lighter weight. In general, you can generally find a ferrite motor that will turn the same prop the same rpm as a more expensive brushless motor- but it can weigh 2x as much – or more.

#### Ferrites-

Ferrite motors use relatively inexpensive ferrite (iron) permanent magnets. These are the cheap can motors produced by Mabuchi for applications such as automotive windows, wipers etc. Some folks have made an art of the care and feeding of these motors, and there are racing classes which use them.

Ferrite and cobalt motors use brushed ESCs- and the ESC's are interchangeable, as long as amp limits are obeyed. In anything larger than Speed 400 applications (i.e. around 1 lb) most ferrite motors need a gearbox for improved efficiency.

#### Cobalts

Cobalt motors use rare earth permanent magnets, which are much more expensive than ferrite magnets. These motors come with ball bearings, and are generally of greater construction quality than ferrite motors.

Cobalt motors are fading from the scene however, because relatively inexpensive brushless motors have largely replaced them. In general, the materials and construction of a cobalt motor and a brushless motor are comparable, and since brushless motors have become more popular, and are being made in greater numbers, the cost of a brushless motor is frequently lower than a cobalt motor of comparable power. The major advantage of a cobalt motor over a brushless motor is the ability to utilize less expensive, brushed speed controls. This savings can be negated by the necessity to use a gearbox for most applications.

#### Brushless motors

Brushless motors come in several flavors. There are high end, high efficiency brushless motors, there are somewhat lower efficiency, moderately priced brushless motors, and there are outrunner brushless motors- i.e. rotating can.

Brushless motors, like the name implies, have eliminated the need for brushes by turning the problem of motor construction on its head. Brushless motors are actually built very differently than brushed motors- they have the magnets attached to the shaft, and utilize windings in the can of the motor. (Rotating can motors put the magnets in the can and rotate that- which is connected to the prop.) By alternating the electric field of the windings, the magnets on the shaft rotate. There is no contact between the shaft and the windings (brushed motors use brushes to carry electrical energy to the windings on the shaft) which has eliminated most of the wear points of an electric motor. The downside to this technology though is that the ESCs are much more complex, and somewhat larger than the more conventional brushed ESCs.

For some years, brushless motors were thought to be beyond the reach of the average modeler in terms of price. However, a few years ago, the introduction of moderately priced brushless motors by Jeti, along with controllers has largely dispelled that perception.

High end brushless motors are produced by Kontronik, Hacker, Aveox, Astro Flight (in smaller sizes) and Maxcim- high efficiency, typically mated to a gearbox, and often an expensive solution.

Moderately priced brushless motors- typically not quite as finely made, but still very sturdy- Jeti and Mega motors. The Jeti Phasor line comes in 3 sizes- the 15 series, 30 series, and 45 series. The numbers refer to the length of the motor in mm. Somewhat coincidentally, the numbers roughly correspond to the power of a glow motor- the 15 is kind of a lazy .15, the 30 would probably be a reasonable .30, and the 45 is a decent .45. All of these motors have various windings- lower numbers means that they spin a smaller prop. Higher number motors such as the 15/4, the 30/3, and the 45/3 all turn typical glow prop sizes, or pretty close to it. In most cases, these motors will have comparable performance to a glow motor, probably lacking a little in the top end department, and a touch heavier when batteries are included. Mega motors use more numbers, but are pretty comparable to the Jeti motors. Mega motors are much happier with gearboxes though.

Outrunner motors-

These motors allow the use of larger props than other motors without the use of a gearbox. I don't have much experience with these motors- but that's going to change soon. For applications where you need better vertical than top end speed, these motors make more sense than the commonly used Mega and Jeti brushless motors. Most common mfg is Axi.

ESCs

Most folks have their favorite brand of ESCs. I've used Jeti, Model Motors, Kontonik (small sizes), FMA, and Castle Creations. I like doing business with Castle Creations- so they're in most of my airplanes. I've also fried at least one ESC from all these mfg- Castle was the nicest to deal with, although a little slow.

Gearboxes

Gearboxes allow you to correctly size the propeller to your airframe. What I have found out about gearboxes- good ones can be nice to use, but aren't cheap-, and cheap ones used above 100 watts should be adjusted with a sledgehammer. One of the most expensive commonly made mistakes is "I got this motor on a good deal." Often, a cheap motor will need an expensive gearbox, which negates any savings. I find gearboxes in general to be an annoyance- so I prefer going direct drive whenever possible. On fast

airplanes, this isn't that much of a problem- but slower airplanes really need gearboxes or outrunner motors.

### Sticker Shock

If you've read this far, and are wondering how much more you're going to have to shell out for an electric power system than your glow motor- you're probably in for a shock. Electric power systems are definitely more expensive than glow- there are no two ways around it. As an example- a JETI Phasor 30/3 with a 35A speed control and batteries is in the \$250 range. Note that this replaces the glow engine, fuel tank, muffler, throttle servo, and receiver battery, but if somebody were to say, that's 2x a glow motor- I wouldn't argue. However, the JETI motor is probably a life time investment- the motor should not wear out in several thousand hours- the only moving parts are the bearings and the shaft. (I have brushless motors with over a 100 flights on them- and they sound the same as they did new.) Speed controls also can last a long time if not abused, and neither of these components should need maintenance. Batteries however, will need to be replaced.

Let me point out though- that what we're really discussing is the difference in cost between a \$400 glow powered airplane, and a \$500 electric powered airplane- yes it's more expensive, but the whole airplane is not 2x more. One other point- the airplane that you don't enjoy flying for whatever reason is a waste of money in my book.

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