Follow-up to the Presentation on Electric Conversion - club meeting October 19, 2010

Here are some points / hints that will help in the construction and installation of an electric system into either an existing nitro airframe or an arf airframe. Some background information for some of these items is attached for anyone who likes to know more of the 'why' and 'how'.

Keep point 8 in mind and do it as soon as possible.

1. Use blue (removable) 'Loctite' thread cement on all motor and mounting screws as you would for any bolts in the airframe.

2. Use the gold bullet connectors that come with the motor and speed controller on the motor-esc side. Buy a pack online to have spares - unless you are a perfect solderer.

3. The battery and the esc come with no connectors. Chose one style for all battery connections. (I chose EC3 , other choices include EC5, XT60, Deans, Powerpole Zero Loss, - as long as it can handle the current, 60A). Tamiya types cannot. **Absolutely** connect one lead entirely before uncovering the second. They must not touch. Observe polarity (+ to +), (- to -) ! Demonstrations of soldering EC3 connectors and others are available on "You Tube"online.

4. Shrink-wrap ALL solder connections. Tape is only adequate until the wires warm up during use. Nutech sells an economical box assortment of shrink tubing.

5. If the motor-esc side wires are elongated to fit your installation, be sure that the wire lengths are identical upon completion. The esc needs motor feedback and uneven lengths interfere with that communication.

6. Twist (loosely - not tight) the three motor-esc leads together to reduce radio interference - especially if the wires were lengthened.

7. If the battery-esc side wires need to be longer to fit your installation, add electrolytic capacitors (2 to 4) to the electronic speed control (the esc) at the battery (input) end to absorb voltage spikes and protect the fets (field effect transistors) on the electronic speed controller. Nutech can get Panasonic Electrolytic Capacitors FM series (low resistance) 50V, 220 μF - $1 each.

8. After selecting and confirming the choice for a particular motor, speed control, ubec, connectors, and battery, connect the components together as they will be in the airplane. Attach the radio system and servos. With no prop, test the system. Note : the electric motor does not "idle". Be sure to set both the throttle stick and the throttle trim to off (minimum) before attaching the battery.

9. Absolutely use a UBEC for batteries over 2 lipo cells. Wire the UBEC (universal battery eliminator circuitry) leads into the same connector as the ESC to attached to the battery. Making some sort of a “Y” connector to keep them separate adds unnecessary wire length and bulk.

10. Cut and glue supports and padding to shape and provide protection in the battery compartment. Stick to one physical size of battery (not the capacity) to easily strap the battery into the battery compartment with velcro. Remember, in a crash landing, the battery will slam forward. Make some sort of forward crash protection.

11. Consider having the connector into which the battery leads will plug fastened to the compartment. This way, one hand can push the leads into use and pull the leads off after flight. I found this easier than fishing for the short esc leads with one hand and pushing in the battery leads with the other. Forces always act in pairs.

12. Mount the radio receiver - which probably has two components - using velcro. It may be necessary to move one around if radio interference is noticed.

13. Use velcro initially to mount the ESC and UBEC and then use nylon ties to strap the ESC in place.

14. A great many arf airplanes that you may have known as nitro models now come nitro and electric ready. They are listed under RC airplanes but often not under RC electric airplanes - see www.greathobbies.com. Check for nitro/electric ready arfs under RC airplanes. Often the manual is downloadable and will provide some conversion insight.

Background information:

The following is unnecessary to your success and is attached for background interest for those few who may want more.

1. Viewpoint: - different systems

Look at electric motor systems in terms what makes sense for electric power and not try to make them fit the liquid fuel framework.

2. Motors Considered: - brushless only

I'll stick with brushless motors except to say that a typical brushed motor, like a speed 400, is only about 40-50% efficient. At best, only about half the watts delivered to the motor actually end up as useful work turning the propeller. The rest is wasted - mostly as heat but some as radio waves. Motors that have a "speed" designation, like speed 400, are brushed motors.
Brushless motors are upwards of 98% efficient.

3. Caution about proper ESC: - only brushless with brushless

Brushless motors require an electronic speed control (ESC) specific to brushless. An ESC for a brushed motor will not work with a brushless motor and vice versa

4. System: Motor, ESC, and Battery - consider together

Regard the battery and the motor as one unit when you are sizing power systems for electric planes. In some cases it may be best to start with the battery when sizing the system. The motor can't deliver the power to the prop if the battery can't deliver the power to the motor.

5. Trying various combinations using on-line calculators:

Personally I think that they are technically overkill but programs like MotoCalc allow you to try all sorts of combinations and makes suggestions on what you should use. The suggestions generally are **not** generic.

MotoCalc will tell you about Amps, Volts, Watts, RPM, Thrust, Rate of Climb, and much more. It is a popular tool for predicting the proper motor, propeller, esc, and battery pack for electric planes.

http://www.motocalc.com/ 30 day free trial then buy for $40US

Configuring and conversion software on most sites (such as greatplanes, hangar 9, etc. provide suggestions in terms of their own products. Additionally, you can enter one of their own planes and you will get back good conversion information - again using their own products.

Electronic Speed Controller - ESC

1. Brushless motors never run at less than full applied voltage:

Forget rheostats. Brushless motors can't use them. Some people mistakenly believe that the ESC changes the voltage to the motor in order to change the speed of the motor. That is not the case. The ESC is not a variable resistor that adjusts the voltage to the motor.
Some mistakenly believe that if they run their motor at partial throttle they are sending reduced voltage to the motor. Not true. Running the motor at ½ throttle does not reduce the voltage to the motor. The motor is getting the full voltage supply every time the ESC switches on.

2. The ESC is a speed controller not a power controller: motor feedback

The esc does not control the amount of power going to the motor, it only controls the speed at which the motor spins. The only information required from the motor is the relative position of the rotor with respect to the stator so the ESC knows which stator coils to energize at any given time. On sensorless systems, the feedback is supplied by a sine wave shaped voltage that is induced into the unenergized winding by the rotating magnetic field of the rotor. (Faraday's induction principle)

(Some older model motors had three Hall Effect sensors to supply feed-back. The output voltage of the Hall Effect sensor is proportional to the strength of the magnetic field in its vicinity.)

Newer brushless motors do not have Hall effect sensors for feed-back. The position of the rotor is known to the ESC from field energizing. The ESC will energize the correct magnet of the 12 or more in sequence to keep the rotor turning in the intended direction.

3. Effect of lengthening wires at installation:

Longer wires may interfere with motor-esc communication and the ESC may not be able to determine rotor direction or position. Keep any extensions at equal length. Place the ESC as close to the motor as possible - which is great for ventilation anyway.

4. Slight stutter at startup

The sensorless motor must be spinning at some marginal speed for the magnetic field to induce a voltage into the un-energized winding that is high enough for the ESC to sense. The result is that the sensorless motor will stutter and not start rotating smoothly until that minimum speed is met. This is usually at some throttle position a click above minimum and it will vary slightly from motor to motor. The delay or stutter is almost imperceptible.

5. What the throttle position is telling the esc:

With relation to throttle position, the motor will attempt to spin at the same speed for a given throttle position, but the actual speed will vary with the load on the motor.

6. The ESC is a fast switch:

In the specifications for the ESC you will see a frequency number likely around 8 KHz but ranging from 2 KHz to 12 KHz or higher. This indicates how fast the ESC can pulse power to the motor. The ESC is a fast switch that pulses power to the motor. You can think of this as a duty cycle control. The ESC turns the power on and off. This means that during every on cycle your motor is getting the full voltage of your battery. The ESC fires as fast as the motor is turning, but the amount of power that goes into each cycle is controlled by the PWM modulation of the signal (PWM = pulse width modulation). At high throttle, the pulse wave is wide and more on-off cycles occur in that open window. At lower throttle, the pulse wave is narrower and fewer on-off cycles occur in that window. Motor speed is varied by varying the ratio of on-time to off-time - not by varying voltage.

7. Rapid switching makes radio interference:

Here is another significant effect as the ESC is switching power on and off.
Let me reference the radio antenna for a moment. The electron packets are pushed up and down the antenna by the radio’s electronics. The rapidly stopping electron must get rid of its energy. It does so by transmitting the energy as an electromagnetic wave - a radio signal. Similarly, charges starting and stopping from the battery to the motor also produce electromagnetic pulses, or radio waves. The electronics in the ESC typically will be designed to reduce or shield some of this radio wave noise, but it can’t block it all. This is why it is recommended to keep the ESC and the receiver as far apart as possible as this ESC noise can interfere with the receiver. If you are getting “glitching” or odd pulses to your servos, these may be coming from ESC noise bothering the receiver. Try moving things around.

8. No throttle means no motor spin: idle doesn’t exist

Another ESC related idiosyncrasy inherent in most Electronic Speed Controls, ESC, is that before the motor will run, the ESC requires that you move the stick to zero throttle. This is a safety feature that prevents the motor from coming on the moment you connect the battery. But, is your throttle stick really at zero? The trim on the throttle channel of glow planes is used to set the idle, so the motor won't shut off when they go to zero throttle position. The throttle isn't really at true zero. Electric models must have the throttle trim set to zero as well. Most newer 2.4 Ghz radios have model memory and will save settings for each plane. If your radio does not, you will need to set idle again for any non-electric planes.

9. ESC cuts off voltage to protect the battery and airplane

The ESC also protects both the radio receiver and the lipo battery in the plane. It will measure the battery voltage and set the lowest voltage that the battery can safely handle. This LVC or low voltage cutoff cuts motor power only. 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. If your motor cuts out, you will need to glide the plane as you approach to land as soon as possible. Learn to glide the plane during regular flights in preparation. After the LVC cuts the load of the motor, the voltage will likely pop back to 3.1 or 3.2 V 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 3.3 V/cell resting but it can't sustain it with the motor running.

10. Short-term compensation from voltage cut-off

Another thing 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 avoid obstacles and properly align to the runway. But don't push it by trying to extend your flight with lots of short bursts. If it will help you avoid a crash, one or two short throttle bursts are worth the risk to the battery. For a manually setting ESC, set the cut-off at something above 2.8V per lithium cell.

11. Use of a BEC / UBEC

Rather than having a separate battery for flight control as in liquid fuel models, many ESCs will have an integrated battery elimination circuit, a BEC to deliver power to the receiver. Generally instructions say that for uses above 11.1V disable the BEC and use a UBEC. There are different kinds of circuits that are used to create the BEC function.

Lower cost linear BECs are integrated in with most ESCs. Linear BECs and UBECs are inefficient and heat up.

> For example: using a 14.8V battery, in order to get a minimal 5V/1A out of the BEC, the input in must be at least 1A. BEC power in is V x I = 14.8 x 1 = 14.8 W. BEC power out is 5W. Efficiency is 33.8% as 9.8W is changed to heat.

Switch mode IC UBECs are about 90% efficient. For example, to get a minimal 5V/1A UBEC output power of 5W requires only 0.38A input - the UBEC input power is 14.8V x 0.38A = 5.6W. The switching UBEC is about 90% efficient with no damaging heat.

Battery: LIPO Battery

1. Batteries should run below their C rating

C is how long it takes to discharge the battery in fractions of an hour.

1 C discharges the battery in	1/1 h or	60 minutes
2 C discharges the battery in	½ h or	30 minutes
5 C discharges the battery in	1/5 h or	12 minutes
10 C discharges the battery in	1/10 h or	6 minutes
30 C discharges the battery in	1/30 h or	2 minutes

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

For example: (see the battery example on the other conversion notes)
A motor needs a battery to supply 50 amps at max throttle. It can get this from
2200 mAh pack that is rated at 25 C running at its limit for 2.4 minutes
5000 mAh pack that is rated at 10 C running at its limit for 6.0 minutes
Better way to go:
5000 mAh pack that is rated at 20 C or better running below its limit
In this case, the pack will be less stressed and should handle the load much better over the long term.

2. Fragility of LIPO batteries

Note that most lipo batteries are 'soft' packs. A few are 'hard-shelled' but not for airplane use.
In balsa or plastic models, be sure to pad the pack so that a crash is less likely to damage the pack. LIPOs can not take the physical abuse that the NiXX packs tolerate.
If you should have the misfortune to crash an electric plane, you must make sure that the battery is not damaged.
If the battery is punctured - leave it to cool several feet away with no flammable nearby.
If the battery does not appear punctured, remove it from the plane, set it on the ground or asphalt away from flammables to cool. Transport in a metal container. Do NOT recharge if damaged or ballooned up.

3. Fire danger if mishandled:

Lipo battery packs must never ever be shorted. The momentary current can be hundreds of amperes both between the contacts and within the battery pack. The rapid heating will likely burst and ignite the pack.

Lipo batteries are used in phones, cameras, computers etc - so don't get paranoid, just respect them with due care.