Model Aviation's Sport Aviator
The e-zine for the new model pilot

Trading Alcohol for Electrons
How to Convert Polk's Hobby Dorothy II to the Dorothy II-E
By Eric Henderson

As you can see from many of the Sport Aviator review articles about electric-powered model airplanes, propulsion systems using electrons for energy have finally become practical. But the selection of airframes designed for electric power still remains limited. However, there are hundreds of ARF and RTF aircraft designed for glow power that can be easily converted to electric.

This article covers the conversion of Polk's Hobby's popular Dorothy II to electric power. But the techniques used here apply to converting just about any airplane with a beam motor mount like the one in the Dorothy II. Other glow-powered ARF aircraft use a firewall engine mount system. Converting a beam mount to electric is more difficult. Converting a firewall mount system usually just requires a plywood spacer which, combined with the motor's supplied mount, positions it further forward so the propeller clears the fuselage.

In this project, I used an aluminum motor mount made from 1.5 inch angle bar stock that is available in any hardware store. I bought mine from a local True Value Hardware store. Aluminum is almost as easy to cut as plywood but is stronger and the angle stock provided a ready-made 90 degree bend.

The OS Max 40 LA-powered review model of the Dorothy II attracted a lot of attention at my local club, The Pine Barons R/C Club based in southern New Jersey. The Sport Aviator review article of this aircraft, The Dorothy II Basic Trainer ARF, can be found in the "On The Flight Line" Section listed under Basic Trainers.

In the original review I had asked the question "Could the Dorothy II be an ARF that bridged the standards of the older beliefs and yet still successfully develop the new breed of ARF trained pilot? "

The answer was a resounding "yes!" and I had expected the airplane to become a trainer for a new or younger club member. While my prediction wasn't wrong, it was a little short of being right. Soon after the test flying session, I was approached by an elder of the club who inquired as to the suitability of the aircraft for electric conversion.

One short conversation and a deal was struck. If he provided the electric parts, I would do the conversion. Bob Emme was the gentleman in question. Bob flew P-51 Mustangs in WW II and has had a life-long love affair with anything that flies. He had the most interesting distinction of being one of the pilots who ferried back captured German airplanes to a base in France.

Sometimes he would be flying airplanes that were of a more experimental nature and which didn't have any manuals. Even if they had instructions, they were not in English!

On a more emotional note we discovered that his wife and the airplane had the same name. So armed with Bob's never-ending spirit of adventure, his electric motor, battery and speed controller, we headed for the workshop.

FIRST STEPS

The first thing that was done was to give the airplane a new designation. The letter "E" was added to the name to help in all of the conversations and the naming of the computer files and digital photographs. The name "Dorothy II-E" became the aircraft's new identity.

The good news was that we already knew that the airplane flew well and also exactly where the CG was supposed to be. The sort-of bad news was that we did not know if the electric motor would be big enough, powerful enough or even heavy enough. It could, of course, be too heavy?

The first step was to remove the glow engine and clean up the airplane with some paper towels and my wife's Windex. Electric planes do not get "oily" like glow-powered models so it had to be clean from the beginning!

Photo 1

Next, Bob and I started removing the parts not needed for the Dorothy II-E. The following items were removed (photo 1):

- Receiver switch with charging lead
- 1100 mAh NiMH receiver battery
- Throttle servo and pushrod
- 10 x 5 APC glow propeller
- Spinner nut
- OS Max 40 LA and muffler
- Fuel tank and tubing/filter.

Once everything was removed, it was much easier to plan the next conversion steps.

EQUIPMENT NEEDED

To complete the Dorothy II-E, additional equipment needs to be gathered and purchased. The radio system did not have to be changed. Any four-channel radio will do the job for this airplane, glow or electric powered. For this review, the Futaba 9CAP was retained. Futaba's 9CAP also allowed the airplane's radio program to be copied onto several other club members' radios for subsequent flight sharing.

Photo 2

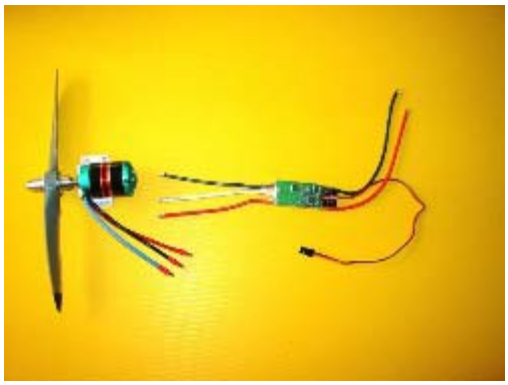

Photo 3

This is what was needed and used to convert the Dorothy II to an electric Dorothy II-E

- A 3-cell, HI-PO Lithium–Polymer (Li-Poly) 11.1 Volt battery like the PQ-4400 mAh battery shown in photo 2. I strongly suggest a battery with a charging guard like the Poly-Quest PQ PCM one (HIPO PQ440 SP36).
- Electric Motor, Himax Outrunner, Brushless HC 3528-1000
- Propeller adapter and a 12 x 8 APC propeller
- Speed controller, Castle Creations Phoenix 60 Amp 12-volt capacity
- Two female Deans style connectors
- Motor mount, supplied with motor or self made
- 4” of 3” x 1/16” balsa sheeting
- Thin CAA super-glue and kicker

PLANNING THE CONVERSION

To convert the airplane to electric power, there were several design areas that needed to be considered:

Motor Installation

Because the airplane came with hardwood beams the decision had to be made whether to remove the beams and use the supplied radial mount or take advantage of the beams existing position and thrust alignment. The motor already came with a radial mount. It was an outrunner type of electric motor that needed room for the casing to rotate both in front and behind the motor mount.

Cooling

The electric motor needs to be kept cool. So does the battery, and more importantly, the electronic speed controller. The speed controller also makes a brushless motor work as an electric motor and in our case supplied the electricity to power the radio receiver and the servos. This saved weight by eliminating the usual receiver battery. (Ed. Note: I*t is possible, and sometimes desirable, to keep the receiver battery. In this case, keep the radio switch in place and connect the receiver battery as usual. If something happens to the motor battery, you still have control to glide the aircraft back to the runway. The Dorothy II is very light and can easily handle the extra receiver battery’s weight.)*


Photo 6 Photo 7

Photos 6 and 7 show some of the areas that must be removed to provide cooling. The new air passages in the firewall allow the motor's cooling air to escape while providing cooling inlet air for the battery and speed controller.


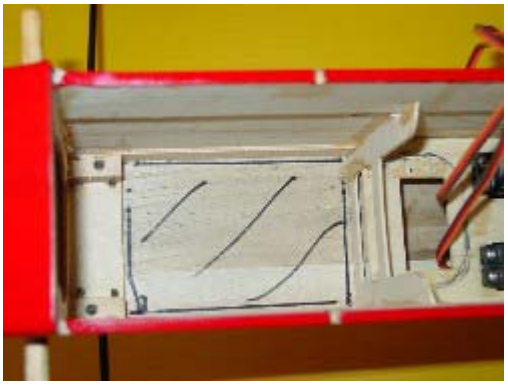

Photo 8 Photo 9

Photos 8 and 9 picture the exhaust air vents that must be cut in the fuselage. The general rule for all cooling air flow is that there should be about twice the area for exhaust as there is for incoming cooling air.

Battery Mount

The battery is a heavy component and needs to be securely fastened in place. It must not be allowed to come loose during flight. At worst, it could disconnect and all power to the radio would be lost. It could also severely change the airplane's center of gravity.

Battery Connection and access/removal

The best practice for a battery installation is to have a system where the battery can be removed quickly for charging/inspection etc. without having to take the airplane apart. The battery would need to be kept cool as well as firmly supported.

Trial Fitting

Photo 10

Before any actual modifications were made, all of the components were placed in the fuselage and temporarily held in place with masking tape. It was easy to see that all of the electrification parts had a place to go. It looked like the conversion would only need a small amount of carpentry.

The next thing to see was if the center of gravity could be maintained without adding any lead weight The firewall cooling and battery mounting holes were cut and the parts were put approximately where they could eventually be installed (photo 10). The airplane at this stage was proving to be a little bit tail-heavy.

The battery and the motor needed to be moved as far forward as they would go. That put the motor at the very front of the engine mounting beams and left the battery half hanging out the front right underneath the motor.

The position of the Electronic Speed Controller (ESC) was, in a way, pre-determined by the length of the wire leads to the motor and the battery. Also the length of servo-type wire lead that plugs into the receiver influenced the placement of the receiver.

The ESC would have to be installed inside the front of the fuselage about half way inside the air tunnel. This was good for cooling, but made it a bit tricky to fasten the ESC in place. It ended up approximately where the old fuel tank used to be positioned.

The receiver could now be moved back out of the air tunnel, away from the electronics of the speed controller and brushless motor. This was a good thing and made for very easy connection of the servos etc. There was no receiver-switch to install because the act of plugging in the battery would power up the radio equipment.

Re-Modeling the Dorothy II

Constructing a Motor Mount

After trial fitting all of the equipment, it was clear that the motor's stock radial mount would not put the motor far enough forward. It was decided to make an alternative mount out of some scrap aluminum angle bracket. This did not require any special tools other than a hacksaw and a file. A drill-press was used to make the necessary holes, but a hand-held drill would have also done the job.


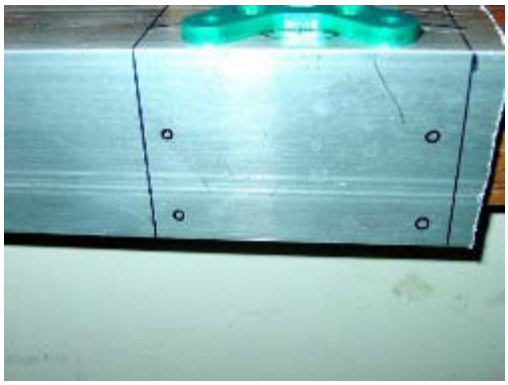

Photo 11 Photo 12

The four-bolt pattern of the OS 40 LA was copied onto the aluminum by placing the new mount on the engine mounting beams and marking them through the existing bolt holes. The motor's stock radial mounting plate was then used as a template to establish the position of the outrunner motor on the bracket (photo 12).

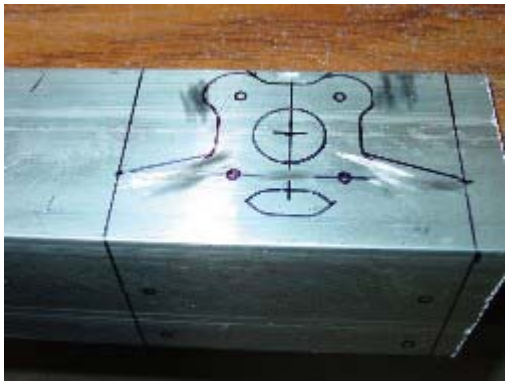

Photo 13

The result was that the motor's center-line ended-up about 1/2" higher than that of the original glow-motor. This should still work because of the down-thrust that was already built into the plane. The only way to be sure would be to see how the power-on and power-off elevator trim would change during the actual test flights.

The following photos illustrate how the mount was constructed better than would a long text. Aluminum drills and cuts easily but it is always best to make sure drill bits are either new or sharpened.

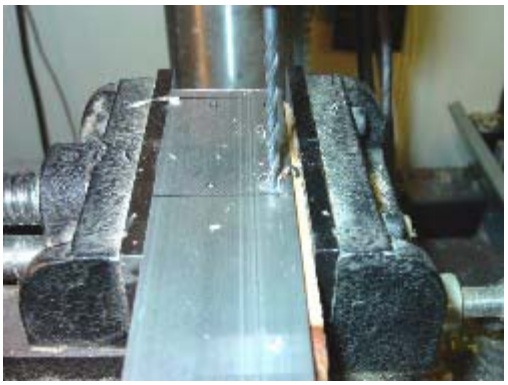
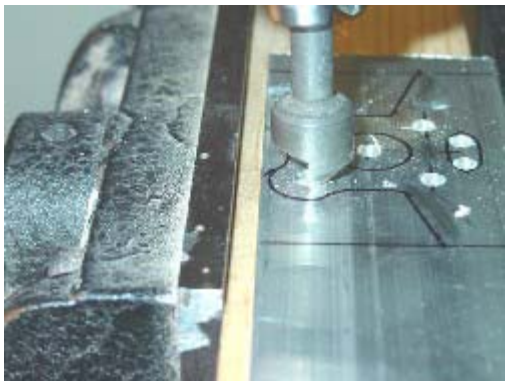

Photo 14 Photo 15

A drill press does make things much easier. I would recommend that you use one if possible. Hand drilling works but it may be hard to keep the drill from “walking” during the initial drilling. Use a punch to indent the aluminum in the center of each hole to be drilled. This helps to keep the drill bit in place at the start. If you have a friend with a drill press, maybe he can help you on this project. Use a counter sink bit to provide space for the screw heads to recess into the metal (photo 15).

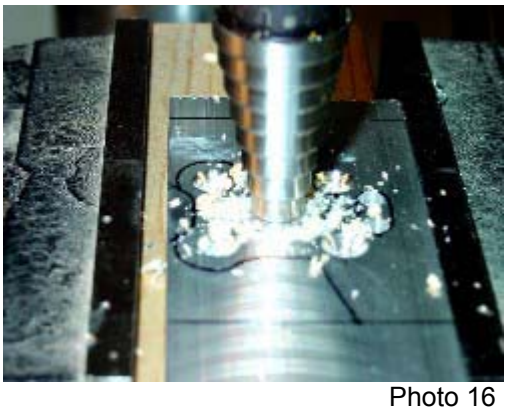


Photo 16 Photo 17

Cutting the larger holes was done using a step drill but regular, larger drill bits can be used. Just remove any rough areas with a round file and then countersink the holes (photo 17).

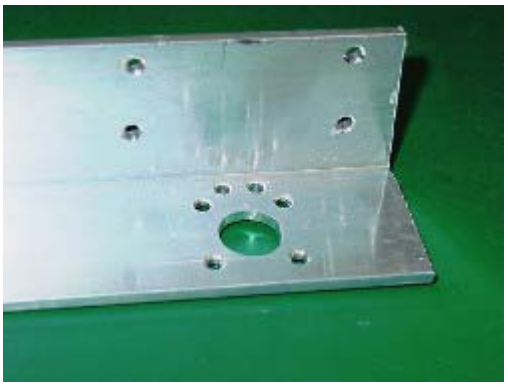
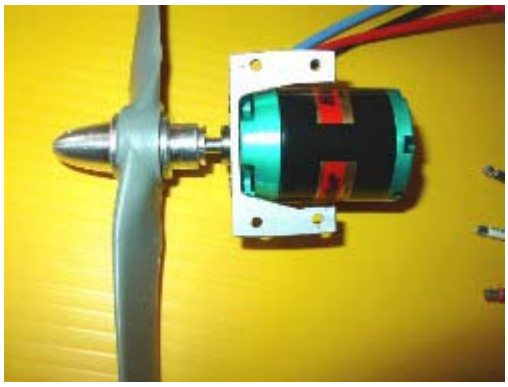

Photo 18 Photo 19

Photo 18 shows the mount with all the holes drilled. This is the side that faces the motor. The holes are countersunk on the other side for the recessed screws. Once everything is drilled, use a

hacksaw to cut the motor mount to shape and test fit the motor (photo 19). Remove as much metal as possible that is not structural and then file the mount's edges to remove rough areas and burrs.

Making the Cooling Holes


Photo 20 Photo 21

To get air into and through the fuselage, the existing firewall was opened up considerably. Pilot holes were drilled at the corners of where the material would be removed. Then a knife-saw was used to cut between the pilot holes. Finally, a Dremel sanding drum was used to smooth out the rough edges of the saw-knife cut. Notice in photo 21 that the firewall areas behind the beams wer4e left intact.

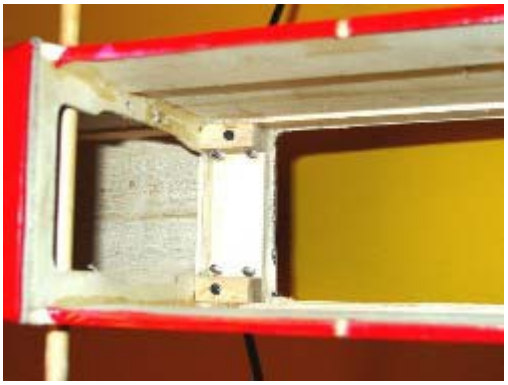


Photo 22 Photo 23

To get air out of the fuselage, a rectangular section of the fuselage floor was removed between the landing gear block and the first former that was holding the servo-tray in place.


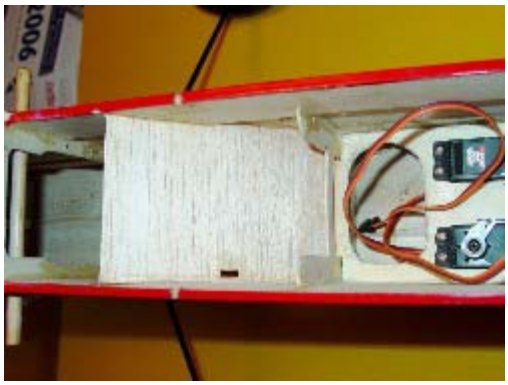

Photo 24 Photo 25

An air deflector was then cut from 1/16” balsa wood and glued at an angle, down towards the new opening in the fuselage. Once the wing was installed, the air dam would prevent the air from going into the rear fuselage section. This creates an air tunnel forcing the cooling air to exit through the bottom of the fuselage. The exit area for cooling air was two to three times greater than the entry area. This would ensure good cooling of the battery and the speed controller. The battery was also exposed to fresh air at the front of the airplane.

Mounting the Battery

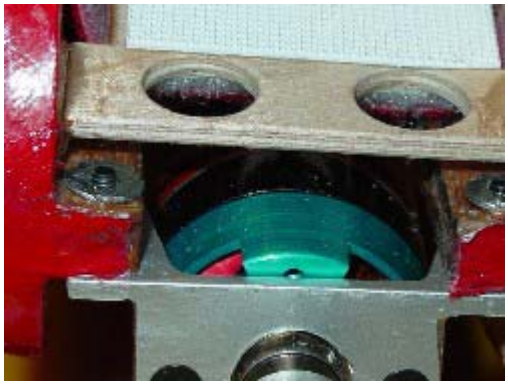

Photo 26

A 1/8” plywood plate was fashioned to hold the battery under and clear of the spinning outrunner motor casing (photo 26). The battery would slide into the fuselage from the front and then be held in place with Velcro® cable-ties that were obtained from a local True-Value hardware store.

Self-adhesive-backed Velcro strips were applied to the 4200 mAh battery and the plate to give extra grip to the Velcro ties. This would prevent the battery pack from moving backwards and forwards during flight operations. Lightening holes were bored in the plywood to allow heat to escape from the battery.

Speed Controller Installation and Location

Photo 27

The ESC was held to the inside wall of the old fuel tank area with self-adhesive-backed Velcro. The balsa wood was prepared with thin CAA which was allowed to cure completely. The Velcro could be attached to this surface and would be very hard to remove. (*Ed. Note: Eric has a good trick here. Coating an area of wood with thin CAA provides a firm, clean and solid surface for the adhesive to stick to. This sometimes even makes wood that has absorbed a little oil "hangable" or "coverable" again. If covering, DO NOT USE HEAT. Use the covering's adhesive activator instead.)*

Self-adhesive-backed Velcro of the opposite gender, was applied to the ESC itself and the unit pressed into place. It was positioned so that the leads would reach the motor and also the battery leads would exit below the motor. This allowed the connection of the battery before it was slid into place under the motor.

Some soldering was required. The ESC needed a Dean's-connector to be fitted to match the battery lead. The Himax motor needed its supplied connectors to be attached to the three wires. Special care was taken to make sure that the heat-shrink insulation covered any exposed wiring.

Setting Up the Radio

The flight settings for the glow version were already in my Futaba 9CAP. It was a simple matter to reset the throttle throws to 100%. *Please note that at this stage you may not be sure which way the throttle will operate!* It could be going forward or may be providing reverse thrust. When working on the motor setup, always remove the propeller. Remember that an electric motor, unlike a glow engine, is always "live." A wrong connection or accidentally moving a switch can start it spinning. *Be careful once that battery is connected.*

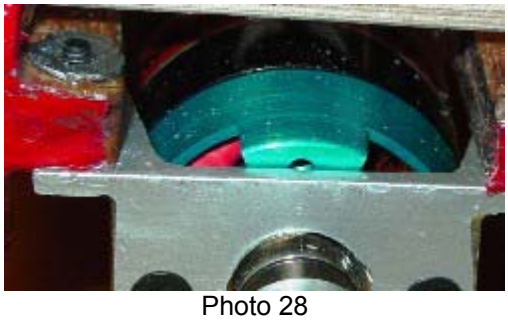

Photo 28

The motor was held in place with the 4-40 bolts that were used to hold in the glow motor. Blind nuts were used on the bottom of the beam mounts so that the bolts would not interfere with the battery mount (photo 28).


Photo 29 Photo 30

Small wire-wraps were used to keep the motor leads away from the outrunner casing. The system was powered up to determine the connection identity of the three wires from the motor to the three wires of the ESC. This tends to be a bit of a “trial and error” process and it is strongly advised that you have a friend hold the airplane while you do this.

With the radio transmitter turned on, and the throttle stick at the low setting position, plug in the battery. Be sure to keep your hands and other valuable parts of your body away from the motor. If the motor rotates clockwise as viewed from the rear of the aircraft, this is the proper direction.

When the battery is plugged in, the ESC will make a series of initialization sounds. Holding the airplane firmly move the throttle to fully open and back down again. Please note that you must follow the instructions that come with the motor and ESC. Those instructions supersede anything that is written for the example in this report.

Slowly advance the throttle until one of three things happens:

1. The ESC makes sounds and the motor does not turn.
2. The motor runs in the correct, clockwise direction.
3. The motor runs backwards.

In the first case, unplug the battery and swap any two of the motor connections and then do it all again. You should get either condition two or three. If the motor runs backwards swap a different two motor/ESC wires and the motor should run correctly.

You only have to do this set-up once. Normal operation consists of switching on the transmitter, moving the throttle to the low position and then plugging in the battery. After the ESC beeps its way though its sensing and initialization procedure, a cycle of the throttle stick will get you ready to fly.

It is not necessary to install the propeller to see which way an outrunner motor is rotating. Look for the clockwise rotation as viewed from the rear. Save installing the propeller for the final step.

The Castle Creations, Electronic Speed Controller (ESC) employs a battery eliminator circuit (BEC). This means that no separate battery pack or switch is needed to power up the radio-receiver and three remaining servos.

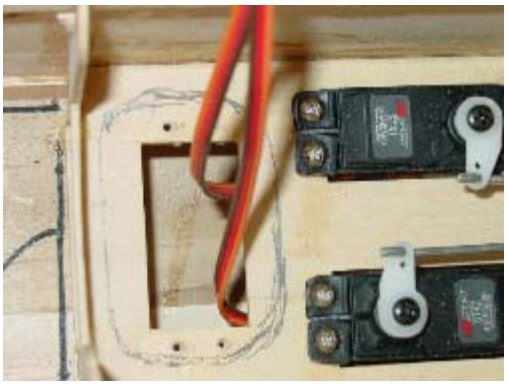
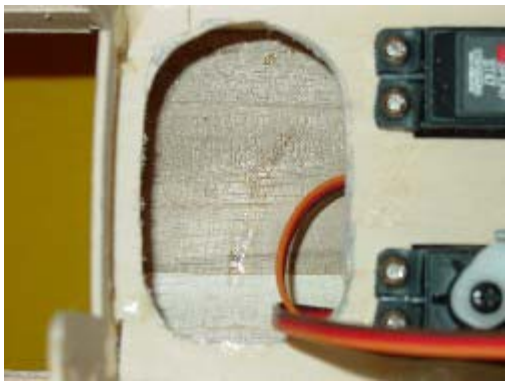

Photo 31 Photo 32

When the throttle servo was removed, a space became open in the servo tray. Enlarge this space to fit the receiver with its foam wrapping as shown in photos 31 and 32.

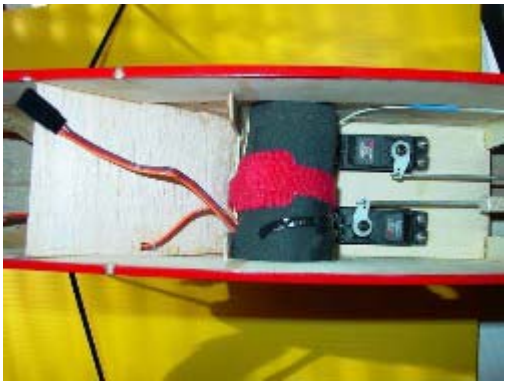
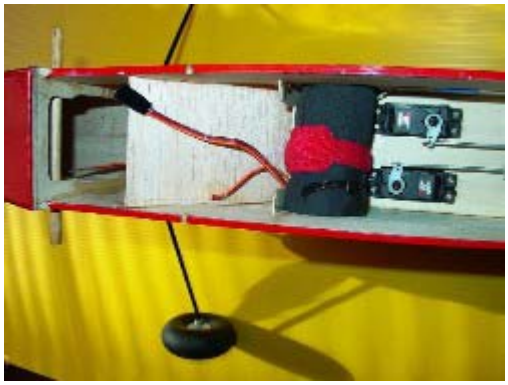

Photo 33 Photo 34

The radio receiver was re-wrapped in foam and repositioned behind the 1/16" air-dam. It nestled perfectly in the enlarged hole where the old throttle servo used to be situated. A Velcro cable-tie through the old throttle servo opening, made sure that the receiver would not move in flight.

Center Of Gravity

This was checked again and found to be exactly the same as the glow-powered version. The conversion was completed in a couple of evenings. Most of the time was consumed with the planning. As my grandfather always said**, "***Measure Twice, Cut Once!"*

Conversion Summary

The electric conversion of the Dorothy II is not very hard to perform. The electrification of a Dorothy II could also be done from the outset of the assembly. A commercially made beam-mount would/could make things go a little faster. The airplane balances correctly with all of the electric equipment on board. The newly born Dorothy II-E really looks the part with an anodized Himax motor sitting up front.

All that was left to do was charge-up the 4200 mAh battery-pack and head for the field. Bob Emme came over to my workshop and picked up the airplane. This was so that he could take it to the field if we got a break in the weather and I was not available to do the honors. It also gave me some much needed work space back in my workshop.

Flight testing January 2006

Photo 35

After spending only a couple of evenings doing the actual conversion, there did not seem to be much chance of any flying time in January. I was both lucky and wrong! Once again, the weather gods were especially kind and there was going to be good enough weather for flying at the end of the week. The predicted 48 degree Fahrenheit temperature would not be bad at all for early January in NJ. Unfortunately, weather predictions do not always come true (photo 35).

There was low bright sun that would play havoc with the video camera. However, there was no real wind to speak of. The Dorothy II-E gathered a small but by now, usual crowd. It was going to be ideal for test flight, especially an electric conversion test flight.


Photo 36

The wing was attached with twelve rubber bands, eight more than were supplied with the kit. Never use just four rubber bands to hold any wing in place. The transmitter was turned on first. The 4200 mAh battery was then connected and installed in the nose to both power up the receiver and to provide the juice to run the electric outrunner motor. As a safety practice, it is a good idea to keep you body parts out of the arc of the propeller or have someone actually hold the airplane. The speed controller made a bunch of beeps as it calibrated to the throttle stick position.

With the motor rotating in the correct direction, a short taxi run was made to get a feel for the available power. The Dorothy II-E was ready to go. (The “E” could either mean electric or experimental at this point). There was a slight wind blowing down the runway. The airplane was pointed into the wind and the motor briefly tested.

Although there was high degree of confidence that the airplane would fly, there was still an experimental nature to project. We also did not know how good the power-to-weight ratio was going to be. Last but not least, it still had to be seen if we had created any thrust-line issues with homemade motor mount.

Photo 37

The color scheme had been changed a little. Two highly-visible fluorescent orange strips had been fitted to the leading edge of the wing to help the “new” pilot have easier orientation in the dull winter weather.

Actual Flying

Photo 38

There were no excuses left so it was “Time to fly!” The peanut gallery held its breath as the throttle was advanced. At about half-throttle stick position the Dorothy II-E advanced down the runway. Advanced is an understatement. The airplane could not wait to get into the air. There was nothing to do as regards the trims because they had not changed from the previous glow-powered flights. After one pass, the throttle was opened up all the way prior to attempting a slow roll. Half way through the roll the motor stopped and I had to add rudder to whip the airplane around to an upright and level attitude.

The instructions on the speed controller said if this ever happened, pull the throttle back and open it up again. With very little height left I pulled the throttle back to the low position and advanced it again. The motor came back to life and gave enough power to allow a safe landing. I made a mental note to attempt future rolls a little higher when doing test flights.

Ground tests showed that the motor was still working but would quit after about ten seconds of full throttle operation. It was believed that the battery was fully charged but it proved not to be the case. One full charge later and we were all set to go. The speed controller had done its job correctly and had detected the cut-off voltage at full throttle. The override feature had allowed a safe landing.

The initial error was a misread of the charger displayed voltages and a sprinkle of over-enthusiasm. The lesson learned was to let the charger complete its cycle of charging all the way to the end.

With a fully-charged battery, it was decided to let Bob Emme fly the Dorothy II-E next. My radio is on Mode-1 so we used the Futaba CAMPAC module to transfer the program over to Bob’s 9CAP.

Thirty seconds later we were ready to put Bob in the air with another experimental aircraft. It was hard not to think back sixty years to the days when this young man was doing something very similar in war-torn Europe. Bob is more than competent as an R/C pilot and is pretty adventurous in the air. I quickly opened up my camera bag, took out the video camera and rushed to the end of the runway to catch this great moment.

Bob did not hang around. He went to half throttle and the airplane was almost instantly airborne. There were many mutterings in the peanut gallery and I kept calling for Bob to slow it down a bit so that the camera could keep up. Bob pleaded that he was only at 1/2 throttle and proceeded to aerobat the airplane all over the sky. So much for structured testing.

This was not going to be a very scientific test of the airplane's capabilities. In truth they had already been done in the OS 40 LA Masportaviator review version. We all settled back and just let Bob have his fun. He was doing multiple loops, Immelmanns, rolls, stall turns and even some outside loops. My protests of, "It's not supposed to do outside loops", were ignored with a big grin as Bob just kept on having a blast.

The countdown timer had been set to go off after 10 minutes. We all watched Bob throttle back and do a very respectable first time landing, albeit in the opposite way to the direction that he took off. His generation gets special privileges at our field!

Bob taxied the Dorothy II-E back with a big smile on his face which really made my day.

Summary

The test flight had gone extremely well. Most of all, we had made one of our WWII veterans a very happy pilot. No longer did he have to heave around heavy flight-boxes and fuel cans. All he had to do was charge up the Thunder Power HI-PO 4200 mAh pack and go flying. The airplane was still very clean apart from some mud splatters from the wet runway. This 72 in. wingspan aircraft was the biggest electric that he had ever flown.

We had not known how good the power to weight ratio was going to be or how long it would last. Last but not least, it still had to be seen if we had created any thrust-line issues with the homemade motor mount. The power and duration was just right. The elevator trim stayed pretty constant throughout the flight.

The fluorescent orange strips on the leading edge of the wing also helped the "new" pilot have easier orientation in the dull winter weather

At a wing span of 72" the Dorothy II-E looks pretty big on the ground. The outrunner motor does not look big enough in this airframe but it was certainly big enough to handle the task. The motor's having a centerline that was a bit higher than the original motor had no noticeable effect on flight performance. The test flights showed that it had no elevator trim effect.

The last thing that Bob said was that he was thinking about buying another Thunder Power battery pack so that he could fly while the other one was charging - Mission complete!

Making the Video

The flying was done at the Pine Barons R/C field in Lumberton, NJ. Even though the snow was all gone, the runway was very wet. It did not stop the airplane from taking off or landing. This video was not orchestrated for the camera. We just gave Bob Emme the freedom of the sky and followed him around with the camera.

The Dorothy II-E behaved perfectly and gave a lot of confidence to the pilot(s). The testing of the airplane had drawn a crowd who could be heard murmuring words of approval and remarking how quickly it left the ground. They commented that the in-flight power was just as good if not better than the original glow engine powered version.

During the filming, a 2-cycle powered airplane joined the Dorothy in the air. The contrasting sound was left on the video tape to show how quiet a powerful electric motor could sound. (*Ed Note: I studied all ten minutes of the video. It appears that whoever was flying the glow-powered aircraft was doing so deliberately in an attempt to destroy the quiet and serene nature of an*

electric-powered aircraft. Even when the glow airplane was on the ground, its pilot continued to constantly "rev" the engine for several minutes and then took off again to make even more noise. I guess there are selfish and inconsiderate idiots in every sport and unfortunately there are a few in model aviation as well.)

Suppliers mentioned:

Polk's Hobby
www.polkshobby.com

Himax
http://www.maxxprod.com

Futaba
http://www.futaba-rc.com

Castle Creations
http://www.castlecreations.com

Thunder Power Hi-Po Battery
http://www.thunderpower-batteries.com

Dorothy II-E Specifications

Motor - Himax Outrunner Brushless HC 3528-1000 (Approx $60.00)
(Prop Adaptor from HiMax also)
Speed Controller - Castle Creations Phoenix 60 Amp 6-10 Cells (Approx $120)
Battery - Hi-Po 11.1V PQ-4400 mAh Lithium Polymer with Poly-Quest PQ PCM Charging guard HIPO PQ440 SP36 3-Cell (Approx $130)
Weight - 4 lb 11.3 oz (1.5 oz lighter than glow version.)
Length - 1300-mm, 52"
Wing span - 1800-mm, 72"
Wing area - 840 square inches
Wing loading - 12.9 oz per square foot
Center of Gravity - at main wing spar location
Right thrust - as per pre-installed rails
Down thrust - as per pre-installed rails
Radio - 4 channel - Futaba 9CAP
Servos - Three (3) JR Sport ST-14 STANDARD servos
RX Battery - None
Prop - Electric APC 12 x 6