"BONNIE-20 ELECTRIC ARF"

ADAPTING TO LI-POLY BATTERIES
By Bob Aberle

Editor's Note: *Extensive data charts follow this article. The charts contain all Bob's data results organized by battery type. Explanatory text accompanies each chart. Read the article first and then refer to the charts, as they are more easily understood after reading this report.*

The Hobby Lobby BONNIE-20 was recently the subject of a detailed review that appears in Sport Aviator's "On The Flight Line" Section. We categorize this airplane as an Almost Ready to Fly (ARF) advanced, electric powered, RC trainer aircraft. Just to review, the BONNIE has 422 square inches of wing area and can vary in weight, depending on the choice of battery packs from 55.1 to 62.9 ounces. Wing loading can vary accordingly, from 18.8 to 21.5 ounces/sq. ft.

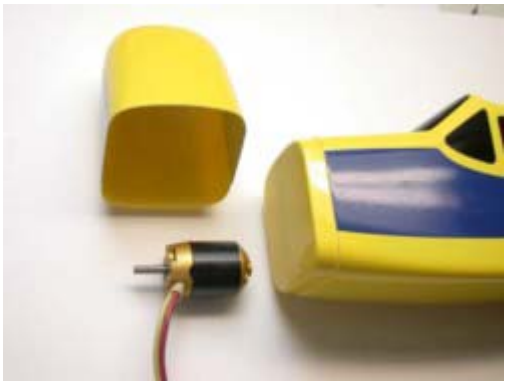

Photo 3 Photo 4

The motor used is an AXI 2820/10 "Outrunner" type brushless motor with a Jeti 40-3P brushless ESC speed controller, (red label, but will explain in the text). The Hobby Lobby recommended battery pack is an 8-cell 1700-mAh NiMH pack. The recommended prop is an APC 10 X 7E. For those interested, the AXI motor designation of 2820/10 refers to the fact that the motor casing is 28 mm in diameter and 20 mm long, with a 10-turn stator!

There are three main battery types used to power electric model aircraft today. The first is the old standby, Nickel Cadmium battery pack (Ni-CD). This is the type battery that powers most radio control receivers and transmitters. Nickel Metal Hydride batteries (NiMH) weigh about the same as Ni-CD batteries but usually have more capacity, more milliamps, for a given cell size (same as regular battery cell size – D cell, AA cell, etc.). The newest and most advanced battery type is called a Lithium Polymer battery (Li-poly). This type offers very lightweight and greater voltage per cell, 3.6 V versus 1.2 per cell for Ni-CD and NiMH batteries.

Photo 5 Photo 6

BONNIE fuselage/tail, with Polk's TRACKER-II transmitter, a tachometer and AstroFlight digital meter and the assortment of battery packs that Bob used in this test series.

A close up showing the Li-Poly battery pack attached to the right side of the AstroFlight digital meter. The other side of the meter plugs into the Jeti ESC located inside the forward fuselage.

The main purpose of this presentation is to first tell you what a NiMH and Ni-CD battery will do with the BONNIE-20. Then go on to show what improvements might be expected when switching over to the new lithium polymer (Li-Poly) batteries. A total of six battery packs were tried on this motor/prop set up (in the BONNIE). One 8-cell 1700 mAh NiMH pack that was recommended by Hobby Lobby, and 8 cell Sanyo1950 FAUP type NiMH pack, an 8-cell CP-1700 mAh Ni-CD pack and three different types of FMA /Kokam Li-Poly battery packs, several of which employed the new 2000 mAh (20C load capable) cells. All data presented here was taken using the same motor and prop (with one exception as noted).

Measurements were made with an AstroFlight digital meter. A check of calibration indicates that this particular meter reads about 0.2 volts on the low side. Initial readings were taken with freshly charged packs at full power. After that, subsequent readings were taken at reduced motor throttle settings of 3/4, 1/2 and 1/4 power. The concept here was to provide current and wattage data for the reduced throttle settings normally recommended during a flight to conserve power and prolong motor run time. Watts/ounce factor was calculated in all cases at an average weight of 60 ounces!

Photo 7

The 6 battery packs used in the test series. The Ni-CD and two NiMH packs are at the top, while the three FMA/Kokam Li-Poly packs are at the bottom. The top right pack is representative of the size associated with an 8 cell CP-1700 Ni-CD pack, but is not the pack I used in my testing. That pack had been loaned and returned prior to taking this photo.

Each battery pack was flown in the BONNIE until just about exhausted of charge. The flight duration was timed in each case and recorded. Immediately upon landing the voltage was measured, under load, to determine exactly how far down the it went during the flight. This is an important consideration for the Li-

Poly batteries. After that, each battery was fully recharged to judge how much power was actually consumed during the flight. Battery pack weight varied from 6.0 to 13.8 ounces. The weight and approx. cost of each battery is listed in the data. Interestingly, the difference in weight from the lightest, to the heaviest battery pack was 7.8 ounces. Each battery was held to a forward plywood tray with the help of hook and fastener tape. The lighter weight packs were moved forward and touched the firewall, while the heavier battery packs were moved aft, closer to the wing leading edge position. Despite the variation in battery weight, the BONNIE flew about the same with each of the six batteries. This is a great testament to the BONNIE's excellent design.

ANALYSIS OF THE DATA

Please refer to the recorded data charts after reading the following. I think it safe to say that the weight differences of the six battery packs ranging from 6.0 to 13.8 ounces made little difference in the way the BONNIE flew. The two NiMH and the one Ni-CD battery packs proved they could fly the BONNIE in an acceptable fashion for periods ranging from 5 to 8 minutes. The time variations result from the way the throttle is managed and the condition of the batteries. You must learn to fly your electric-powered model at only a throttle setting that produces good flight. Don't just automatically go for full throttle and leave it that way for the entire flight. Doing that, you simply get a fast, but brief flight! You won't be happy with that. Also make sure you cycle your NiMH packs often. Even during one flying session, succeeding flights with a particular NiMH pack will improve (fly longer) as the pack gets used more.

Photo 7A

The star players, the FMA/Kokam line of 2.0 AH Li-Poly battery packs as evaluated in this article.

Photo 8

Pointing to the special connector added by FMA/Kokam to let you monitor individually each of the three cells within this Li-Poly battery pack.

The cost of these three NiMH and Ni-CD batteries ranged from $40 to $70. That isn't a lot and allows you to buy several packs so that one can be on charge while the other is flying your aircraft.

As discussed in the original BONNIE review article, I used only the plywood floor of the BONNIE battery box. To this floor I attached half of the popular hook and fastener tape. The other, or mating, half is affixed to the battery pack. By doing this, I was able to easily swap any and all six packs in just a few moments. Also note that my choice of battery connectors is the Anderson Power Pole (APP) type, which for years also went under the name, Sermos Connectors. When you consider motor currents upwards of 32-33 amps, you must use a connector that has this kind of current carrying capability. You might also choose Deans Ultra connectors or AstroFlight's Zero Loss connectors. All three would easily suit this application.

Photo 9

Although all six battery packs flew the BONNIE quite well, the fact remains that when using the two “3S” Li-Poly packs (that’s three cells in series!) the flight performance was spectacular. There is no other way to describe it! At a 32-amp full throttle, on a “3S”Li-Poly pack, the BONNIE takes off in about 15 feet and climbs out almost vertically. You are able to quickly throttle back and still have performance that allows for loops from level flight. By throttling back you reduce the motor current and that extends the motor run times. On the “3S” packs I was able to obtain as much as 11-minute motor runs, which is 3 minutes more than was obtained on the best NiMH pack. One of the “3S” packs with 15C load-capable cells costs $83, while the newer type HD cells, that are 20C load capable, will cost $126. The 15C Li-Poly pack at $83.00 gets pretty close in price to one of the NiMH packs that sells for $70.

Photo 10

Looking inside the forward fuselage of the BONNIE. You can see the Li-Poly battery pack resting on the plywood battery tray. The battery pack is attached to the plywood with the help of hook and fastener tape.

I also tried a “2S2P combination of Li-Poly 20C load capable cells. The cost of this pack will likely be around $160. The weight of the pack is only 10.4 ounces, which is close to the NiMH packs. The “2S” Li-Poly configuration produces the lowest nominal voltage of all the packs tested in this group. As such, the flight had to be flown at close to full throttle, most of the time. But since the batteries are wired in parallel, the capacity gets doubled to 4.0 AH. Doing that extends the motor run time upwards to 16, possibly as high as 20, minutes. You are paying for this extra flight time and you may suffer with somewhat of a slower or “sluggish” flight performance because of the lower voltage.

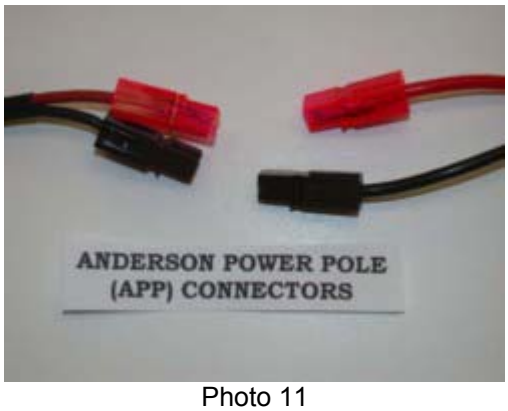

Photo 11

Anderson Power Pole connectors are recommended because the motor current can be as high as 32 –33 amps!

Several thoughts occurred to me after my flight testing with these various battery packs. The “3S1P” 2000 mAh Li-Poly pack made with the 15C load capable cells costs $83.00 and weighs 6.0 ounces. If I were to take two of these packs and wire them in parallel I would then have a “3S2P” pack that cost $166.00 and weighed 12.0 ounces. With that battery pack, I could obtain the occasional 32-amp motor current and could also throttle back below 1/2 throttle. That should provide max-out type performance, along with estimated motor run time of 16 to 20 minutes. That pack still could be brought back to 90% of full charge in a little less than one hour. I think that combination of Li-Poly cells might be explored! I certainly hope to try it!

Photo 12

If you alternate between using Ni-CD/NiMH batteries and Li-Poly batteries, you will need two chargers. Pictured at the left is the popular AstroFlight 109 Lithium charger while at the right is their Model 110 Deluxe peak detect charger that handles the Ni-CD and NiMH batteries. ***NEVER, EVER ATTEMPT TO USE THIS CHARGER ON LITHIUM CELLS****!*

Another thought that comes to mind is that these different battery packs are all extremely easy to swap around. If I did purchase the FMA/Kokam “3S2P” battery pack at $166.00, why not also have on hand two of the 8-cell CP-1700 Ni-CD packs or two of the 8-cell Sanyo 1950 FAUP type NiMH packs. You could make a 15 minute plus flight on the 3S2P Li-Poly battery, then put it on charge. Next, go to the NiMH or Ni-CD pack and make a 7-8 minute flight. When that flight is over put that pack on a peak detect charger and let it charge up in a 20-30 minute period. Proceed to fly on the second NiMH or Ni-CD pack. By the time your third flight is over, your original Li-Poly pack should be close to full charge. Your first NiMH or Ni-CD pack may also have reached full charge. I think you can appreciate this scenario. By being careful with your battery management you can fly literally for hours on three different battery packs. This technique will also be a lot less expensive than having three “3S2P” LI-Poly battery packs, which would be worth almost $500.00!

Photo 13

This is Bob's charging station set up in his shop. Note that the Li-Poly battery is sitting on a large ceramic tile. There is a smoke alarm and a fire extinguisher present.

One of my other brief experiments while flying the BONNIE with the Li-Poly battery packs was to see the affect of switching to a lower pitch prop. I thought going from the recommended APC 10 X 7E to a 10 X 6E might be worth a try. Unfortunately, APC does not make an "E" model in a 10 X 6, so I settled for a 10 X 5E. I did this in an attempt to reduce the 32 amps motor current that I obtained on a "3S" Li-Poly battery. As you will see in the data sheet, I was able to reduce the motor current from near 32 amps down to 24.7 amps (at full throttle). But with this lower current the BONNIE no longer flew well on 3/8 throttle settings. In fact, it required 1/2 to 3/4 throttle settings. I also noted that at the 6-minute point in the flight, the BONNIE was really beginning to slow down. By 7:23 I was totally out of power and had to land.

Photo 14

Using the AstroFlight Model 109 charger operating off a car battery to charge a Li-Poly battery pack.

Looking back over this I realized that with the 10 X 7E prop and a lot of throttling back I was able to obtain an 11-minute motor run time and some "hot" performance. With the 10 X 5E prop I had to use more throttle and I got only a little more than a 7-minute flight time. The bottom line here is that the recommended APC 10 X 7E prop seems the right choice. You will see some comments on this subject from my flying partner, Tom Hunt in the data sheet information.

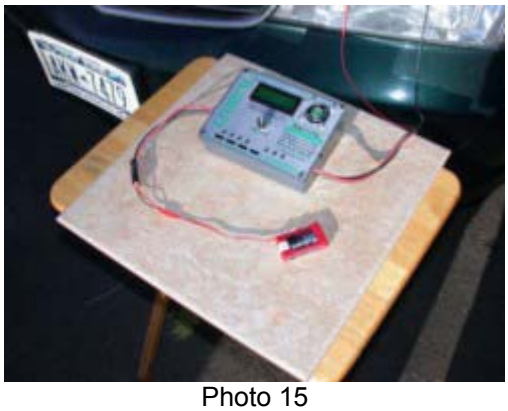

Photo 15

The Li-Poly battery is resting on a large ceramic tile, sitting on an old snack table. Don't ever place the battery up inside the motor compartment or on the engine block of your car.

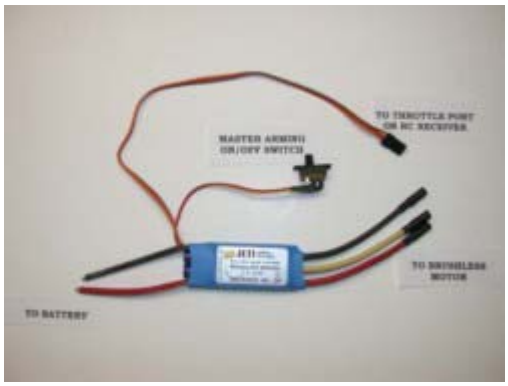

Photo 16

As mentioned earlier, and in my first BONNIE article, Hobby Lobby provided me with their Jeti 40-3P brushless ESC with BEC. This was the red label ESC that was intended for NiMH and Ni-CD batteries. This ESC is set for a 5.5 volt cut-off point. That was fine for my NiMH and Ni-CD batteries. It was also OK when I used a "2S" Li-Poly battery because the minimum desired voltage of 2.5 volts per cell, would be just right for a two-cell pack considering a 5.5 volts cut-off. But when going up to the "3S" Li-Poly battery the minimum discharge voltage should be 7.5 volts. With the red label ESC I had my three-cell Li-Poly battery go below 7 volts and that made me a little nervous. Continuing to do this would quickly reduce the life of these cells.

Enter, at this point, a newly designed Jeti "Advanced" 40-3P ESC with a blue label for identification purposes. This new ESC has several advantages that can benefit both a Ni-CD/NiMH and/or a Li-Poly user. First of all, it has an auto cell sensing function that determines the type of battery as well as the number of cells employed. It then sets the voltage cut-off point automatically for the particular battery. That means you can keep swapping Ni-CD, NiMH and Li-Poly battery packs and have the confidence that your voltage cut-off will always occur at the correct level. This is very important when using Li-Poly batteries.

This new "blue label" Jeti ESC also has two different brushless motor timing modes to achieve even better motor efficiency. As received, the ESC is set for the "soft timing mode". You are advised if using the AXI brushless motor service (as we are here with the BONNIE) to set the ESC for the "hard timing mode". This is a simple procedure involving moving the Tx throttle control stick and listening for a series of five audible beeps or double beeps. Once set up for the hard timing your AXI motor will draw more current and have higher rpm (up to 20% more), with the same prop and battery pack. I think this new Jeti ESC is the way to go in the future!

Overall I feel that the Hobby Lobby BONNIE-20 is the perfect subject for an advanced electric trainer aircraft. It is a smooth flyer and can do so many of the regular aerobatic maneuvers that it will surprise you. While it flys well on the traditional Ni-CD and NiMH battery packs, it becomes a spectacular

performer when you “move up” to a three-cell Li-Poly battery pack. That pack will cost you a little more and will force you to learn some new battery handling techniques, but in the interest of improved flight performance, the Li-Poly’s are the way of the future. If you want to learn more about Li-Poly batteries and their “care and feeding” I refer you to my feature article, titled “Introduction to Lithium Polymer Batteries”, that appeared in the May 2004 issue of MODEL AVIATION.

In a few months look for my follow-up article showing how to fly the BONNIE off water with a specially designed set of floats. Until then!

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HOBBY LOBBY INTERNATIONAL
BONNIE-20 ARF
ELECTRIC AEROBATIC TRAINER

(How to replace NiMh or Ni-CD with Li-Poly Batteries)

TEST DATA

All data was taken with an AXI 2820/10 outrunner type brushless motor, Jeti 40-3P Brushless ESC (red label) and an APC 10 X 7E prop --- except where noted.

(1) - 8-cell 1700 mAh NiMH (Hobby Lobby recommended pack)
Weight: 9.8 ounces, Cost: $64.90

Flight time: 4:49, mostly at 3/4 throttle
@ Full Throttle: 22.8 amps, 7.6 volts, 170 watts, 2.83 watts/oz, 6900rpm
@3/4 Throttle: 18.2 amps, 146 watts, 2.43 watts/oz
@ 1/2 Throttle: 13.8 amps, 108 watts, 1.80 watts/oz
@1/4 Throttle: 7.0 amps, 69 watts, 1.15 watts/oz

BONNIE flight performance at 3/4 throttle was comfortable. Lower throttle settings produced sluggish performance. So the 2.43 watts/oz factor appears to be about the minimum for this aircraft. The 5.5 volt cut-off point on this Jeti ESC was not attained during this flight. The Bonnie simply wanted to land before that happened.

I must admit that this particular battery pack was brand new and was not subject to very many cycles before this “data” flight was made. As such it is assumed that some amount of increase in flight time might be expected after this pack had been “exercised” somewhat. That might tend to bring it back more in-line with the other NiMH pack and the Ni-CD pack (at 7 or 8 minutes motor run time!).

Recharging this battery at a 2C rate (3.4 amps) took 34 minutes with roughly 1700 mAh going back into the pack. So this pack was totally depleted during the 4:49 flight time.

(2) - 8-cell Sanyo 1950 FAUP 4/5A NiMH type
Weight: 11.7 ounces, Cost - $4.50 per cell (approx. $45.00 assembled in a pack) purchased from Dynamo Electrics Co.

Flight time: 8:43, mostly 1/2 to 3/4 throttle settings
@Full Throttle: 26.6 amps, 8.5 volts, 220 watts, 3.92 watts/oz, 7800 rpm
@ 3/4 Throttle: 19.6 amps, 172 watts, 2.87 watts/oz
@1/2 Throttle: 15.2 amps, 141 watts, 2.35 watts/oz
@ 1/4 Throttle: 6.8 amps, 67 watts, 1.12 watts/oz

The voltage drop was less with this NiMH pack than it was with either the previous NiMH or Ni-CD packs. As such the BONNIE was able to comfortably fly at 1/2 to 3/4 throttle settings and was able to loop from level flight at 6 minutes into the flight. The pack was warm to slightly hot on landing. Of the three "conventional" battery packs this pack provided the longest motor run. It could also be completely recharged in less than 30 minutes time.

(3) - 8-cell CP-1700 SCR Ni-CD (Sanyo 4/5 Sub-C size cell) purchased from Batteries America.
Weight: 13.8 ounces, Cost $4.25 per cell or roughly $40.00 for a fully assembled pack. This was the least expensive pack of all tested.

Flight time: 7:16, mostly at throttle settings of 1/2 to 3/4 power
@ Full Throttle: 27 amps, 8.1 volts, 221 watts, 3.68 watts/oz, 7300 rpm
@ 3/4 Throttle: 21 amps, 197 watts, 3.28 watts/oz.
@1/2 Throttle: 15.1 amps, 141 watts, 2.35 watts/oz.
@ 1/4 Throttle: 8.8 amps, 88 watts, 1.47 watts/oz.

BONNIE flew well at 3/4 throttle settings. It started to get more and more "sluggish" when approaching 1/2 throttle. But this Ni-CD battery clearly provided more motor run time than the 8-cell NiMH pack tested first in this data presentation. This pack does weigh more than that NiMH pack (plus 4.0 ounces) but quite honestly that difference was not noted in the BONNIE flight performance. This pack is also a little less expensive than the NiMH pack. The 5.5-volt cut-off point on this Jeti ESC was not attained during his flight. The Bonnie simply wanted to land before that happened.

Recharging this battery at a 3C rate (5.1 amps) took approx. 20 minutes with just about 1700 mAh going back into the pack. Again this pack was totally taken down during the 7:16 flight.

(4) - FMA/Kokam 2 cell, 2 in parallel (2S2P) 2.0 AH capacity (20C load capable) Li-Poly battery pack.

Weight: 10.4 ounces, Cost: not settled as yet but estimated to be around $160.00.

Flight time: 16:00, mostly at 3/4 to full throttle settings
@ Full Throttle: 20.4 amps, 7.20 volts, 153 watts, 2.55 watts/oz, 6900 rpm
@3/4 Throttle: 15.6 amps, 114 watts, 1.90 watts/oz.
@1/2 Throttle: 11.0 amps, 82 watts, 1.37 watts/oz.
@ 1/4 Throttle: 5.8 amps, 46 watts, 0.77 watts/oz.

As you can see the BONNIE performance was degraded by the fact that the two Li-Poly cells provided much lower voltage, therefore lower current and wattage. The minimum figure of 2.4 to 2.5 watts/oz. prevailed through most of the flight. This particular battery was the heaviest of the three Li-Poly packs tried because it was made up of a total of four cells. The flight time was more than both the NiMH and the Ni-CD packs, but the performance of the BONNIE was somewhat strained to say the least.

Recharging on an Astro Flight Model 109 charger, set at 4.0 amps, took 1:00 with 3113 mAh going back into the battery. So the battery was not fully depleted during the flight and may have supplied even more motor run time. Also at the end of the flight the voltage had dropped off to 6.6 volts, which is still above the 5.0 to 6.0 volts recommended minimum for a 2 cell (in series) Li-Poly battery.

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(5) - FMA/Kokam 3 cell, (3S1P) 2.0 AH capacity (20C load capable) Li-Poly battery pack.

Weight: 8.3 ounces, Cost: $126.95

Flight Time: 11:10, mostly at only 3/8 (below 1/2) throttle settings
@Full Throttle: 32.7 amps, 10.0 volts, 318 watts, 5.30 watts/oz., 8800 rpm
@ 3/4 Throttle: 24 amps, 250 watts, 4.17 watts/oz.
@ 1/2 Throttle: 18.5 amps, 198 watts, 3.30 watts/oz.
@ 3/8 Throttle: 14.0 amps, 152 watts, 2.53 watts/oz.
@1/4 Throttle: 5.7 amps, 65 watts, 1.08 watts/oz.

BONNIE's flight performance at full throttle (32 amps) was spectacular! It was off the ground in about 15 feet and climbed almost straight up. It drew the attention of everyone at the flying field. The throttle was quickly reduced to below half, and even at that all the regular maneuvers could be performed including loops from level flight.

Keep in mind that at 32 amps motor current the load is at 16C using a battery that is capable of up to 20 C loads!

Recharging on an Astro Flight Model 109 charger, set at 2.0 amps, took 1:17 with 1845 mAh going back into the battery. The battery in this case was not quite fully depleted during the flight. Also at the end of the flight the voltage had dropped off to 8.2 volts, which is still above the 7.5 volts recommended minimum for a 3 cell (in series) Li-Poly battery. The regular (red label) Jeti ESC with a cut off of 5.5 volts would normally be too low a cut-off when using three Li-Poly batteries. But the fact of the matter is that the BONNIE wanted to land, while the voltage had only come down to 8.2 volts. The better way to go in the future is the new Jeti ESC (blue label), which sets the voltage cut-off automatically for the particular battery in use --- a good idea!

(5A) - This same Li-Poly battery pack was tried with an **APC 10 X 5E prop**, with the idea of reducing motor current to something less than the rather high 32 amps (when using the APC 10 X 7E prop), and yet see if the plane would fly reasonably well. This is the data taken with the same FMA/Kokam 3S1P 2.0 AH (20C load capable) battery and the **10 X 5E** APC prop:

Flight Time: 7:23 minutes, mostly at 3/4 throttle settings
@ Full Throttle: 24.7 amps, 10.2 volts, 246 watts, 4.10 watts/oz., 9800 rpm
@ 3/4 Throttle: 18.4 amps, 197 watts, 3.28 watts/oz
@1/2 Throttle: 14.2 amps, 157 watts, 2.62 watts/oz
@ 1/4 Throttle: 7.2 amps, 84 watts, 1.40 watts/oz

The BONNIE flew well at 3/4 throttle settings but at only 6 minutes into the flight it noticeably began to slow down. By 7:23 the flight was over. A subsequent check of the voltage under load, after the flight, showed that the voltage had dropped down to 6.1 volts and was falling fast. This is much lower than the recommended 2.5 volts minimum per cell.

The interesting point here is that when using a 10 X 7E prop at 3/8 throttle I obtained an 11-minute motor run with "peppy" performance. But when I dropped to a 10 X 5E prop, I had to go up to a 3/4 throttle settings and at that rate could only obtain a 7-minute flight time. The higher pitched prop, running at less current, produced the longer motor run time. In retrospect it might have been wiser on my part to reduce the prop diameter to 9 inches, but keep the pitch still at 7! My flying partner, Tom Hunt, suggests that the wing loading of this BONNIE, though pretty light, still might require that the model go faster to fly longer! That's something to think about!

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(6)- FMA/Kokam 3 cell, (3S1P) 2.0 AH capacity (15C load capable) Li-Poly battery pack.

Weight: 6.0 ounces, Cost: $83.50

Flight Time: 8:20, mostly at 1/2 throttle!
@ Full Throttle: 32 amps, 9.3 volts, 319 watts, 5.32 watts/oz, 8300 rpm
@ 3/4 Throttle: 24.9 amps, 264 watts, 4.40 watts/oz.
@1/2 Throttle: 18.2 amps, 209 watts, 3.48 watts/oz.

@ 1/4 Throttle: 9.6 amps, 110 watts, 1.83 watts/oz.

BONNIE's flight performance once again at full throttle (32 amps) was spectacular! Reducing the throttle immediately to half still provided complete aerobatic flight capability.

The basic differences between this Li-Poly pack and the previous is the load capability, weight of the pack and the cost. This pack is only load capable to 15C, yet the load I impose when at 32 amps motor current is actually 16C.But by reducing the throttle you are down well within the limits of a 15C load. This pack weighs only 6.0 ounces or 2.3 ounces lighter than the 20C load capable pack. And finally this pack can be purchased for $83.50, which is only a little more than you would pay for the recommended NiMH battery (but with almost twice the motor run capability!).

Recharging on an Astro Flight Model 109 charger, set at 2.0 amps, took 1:12 with 1866 mAh going back into the battery. The battery in this case again was not quite fully depleted during the flight. Also at the end of the flight the voltage had dropped off to 7.6 volts, which is still above the 7.5 volts recommended minimum for a 3 cell (in series) Li-Poly battery. Obviously these 15C load capable cells tends to get hit a little "harder" than the higher load capable 20C cells, with the voltage dropping off a little more. Still, the BONNIE wanted to be back on the ground before that voltage dropped below the 7.5-volt minimum for three Li-Poly cells.