Lithium-Polymer Cells for Micro Flyers

A Dream Come True

By Gordon Johnson

For about a year now we have been hearing that Lithium-Polymer (LiPoly) cells were on the horizon and had the potential to dramatically change the micro flyer world because of their high capacity and light weight. LiPoly cells are just beginning to be available in the smaller sizes we are interested in for micro planes. And, they live up to their promise. The cells that are the focus of this article are the 135mAh (145mAh maximum) LiPoly cells manufactured by Kokam Engineering in Korea. I purchased my cells and charger from Skyborn Electronics and found them to be extremely knowledgeable and helpful. With a nominal voltage of 3.7v (4.2v max) these cells at 3.6g weigh just a tenth of a gram more than a single 50mAh Nicad. This results in a savings compared to Nicads or NiMH of 3.4g on a two-cell pack and 6.9g on a three-cell pack. And, one of these cells yields the performance of a three-cell pack on the weight of a single cell.

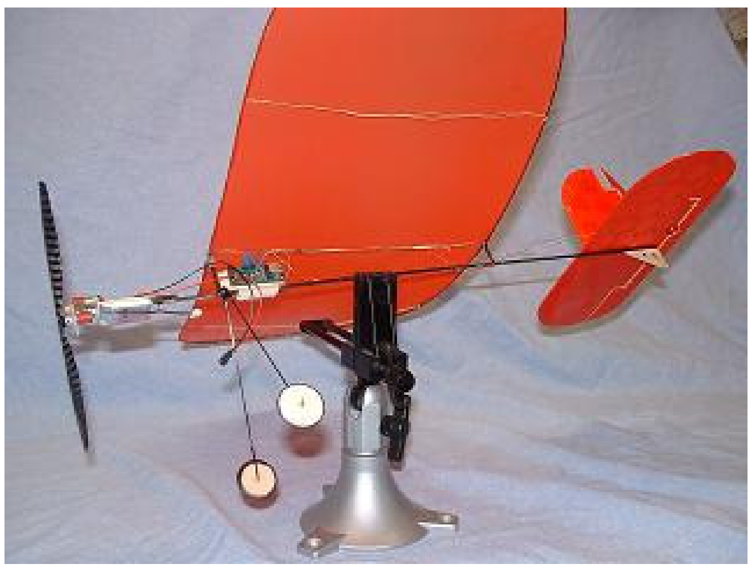
Shown above, left to right are a single 120mAh NiMH cell, a bare 135mAh LiPoly cell, a LiPoly cell with wires and plug soldered on and encased in light-weight clear shrink, and a 120x3 NiMH pack. I label each of my battery packs and keep a log to monitor each pack's charging history.

I started doing static tests with these cells the day after I received them. The focus of my tests was on propulsion systems that are commonly used in small indoor planes utilizing the Dynamics Unlimited RFFS-100 or Ruijsink MicroMag system. An article by Don Strull in the August 2002 RC Microflight has previously demonstrated with constant discharge curves how these cells and the larger 570mAh cells perform. The focus of this article is on static tests with geared motors and props to evaluate static thrust and other measures for 135x1 LiPoly, 50x3 NiCd, and 120x3 NiMH packs to see whether the LiPoly cell could replace either or both of these packs. The results of static tests should always be taken with a grain of salt. A more complete discussion of interpreting static tests follows later in the article. However, the short answer is that the LiPoly cell can replace the NiCd or NiMH pack, but with some caveats

The 10mm diameter Mabuchi M20 in one of its variations is very common for small indoor RFFS-100 and other actuator-based models, particularly as delivered in the KP-00 from Knight and Pridham in 2.7:1 and 5:1 gear ratios. More recently Didel in Switzerland has begun offering gears and gearboxes that allow the M20 to be geared even higher. For these tests I used both the M20-LV (low volt) from an E-Charger toy plane and the M20-HV (high volt) available from Toytronics. The E-Charger M20-LV is very similar to the motor that comes in the KP-00. I used a Kenway 10t pinion from Dave Lewis and 60t spur gear from Didel to obtain 6:1 gearing. I used a GWS 5x3.0 inch prop since it is commonly available and works well with this gearing. I chose this prop size and gearing as the prop would clear the ground on a 13-inch span Fokker Dr1 triplane I had been building in anticipation of using a LiPoly cell in it.

LiPoly Details

First some details. A single 135mAh LiPoly cell weighs 3.6g bare, but 4.1g with wires, JST plug, and shrink wrap. A corresponding 50mAh NiCd or 120mAh NiMH 3-cell pack weighs 11.7g. So, the effective weight of the LiPoly is 65% less. This allows building micro planes where the battery is not the dominant weight.



Here a LiPoly battery is mounted on my Stechmücke with magnets. At 4.1g complete, the battery makes up just 18% of the plane's total 23.4g weight.

A NiCd has a 1.2v nominal voltage, a NiMH has about a 1.1v nominal voltage, and a LiPoly cell has a 3.7v nominal voltage. This higher energy density makes a single LiPoly cell roughly equivalent to a three-cell pack of either NiCd or NiMH cells. However, discharging a LiPoly cell below 3.0 volts can result in damage to the cell and loss of about half its capacity. So, care must be taken to avoid over-discharging below 3.0 volts (some say 2.7v, but I stuck with 3.0 to be on the safe side). Some LiPoly cells come with a protection circuit which prevents discharging below 3.0 volts and also prevents discharging at more than some maximum discharge rate. The cells I received did not have the protection circuit, so I cannot comment on it. However, a hard cut-off at 3.0 volts may not be desirable as the power to the receiver would also be cut off. FMA Direct is working on solutions that include special ESC's, and may be available by the time you read this. Sky Hooks & Rigging sells a hybrid receivers with a built in ESC that has an adjustable cutoff that is perfect for LiPoly cells, especially two-cell packs. The

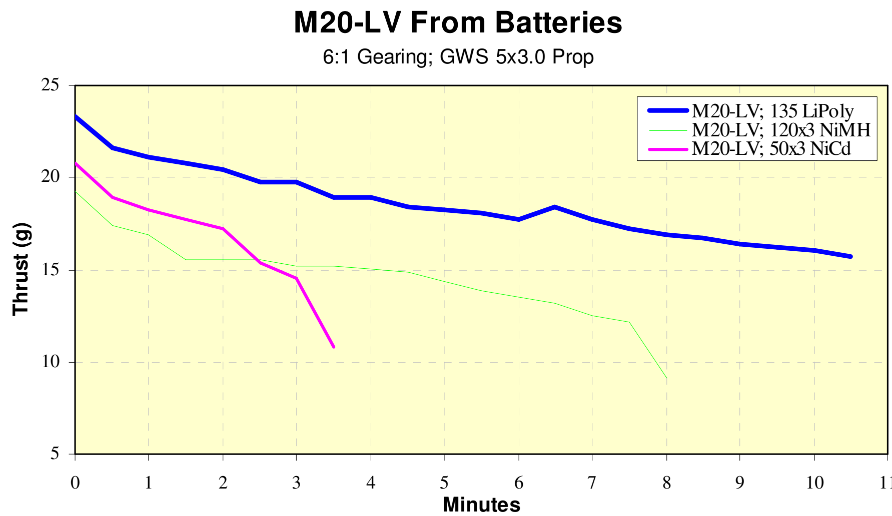
Dynamics Unlimited RFFS-100 does not have a BEC. So, for now the solution is to understand how long you can fly your model at your normal throttle level before reaching the 3.0 volt level. As the tests show, the duration possible with these cells is sufficiently long that landing early for most of us shouldn't be a problem.

The manufacturer does not recommend discharging these cells at more than two-times capacity. However, we generally discharge our NiCd and NiMH cells at more than what the manufacturers recommend. It's still too early to know what effect high discharge rates will have on the life of these cells. We are also still learning what these cells are capable of. If you take the LiPoly plunge you should understand that this is a new area and not everything is known. After all that, there seems to be a consensus developing that discharge rates for the 135mAh Kokam's should not exceed 1 amp, or about 7.4 times their rated capacity. The same is not necessarily true for other brands or sizes of LiPoly cells. Another difference between LiPolys and NiCd's and NiMH's is fast charging times in the field. A fast charge for these LiPoly cells from a fully discharged state of 3v takes roughly 70 minutes. To avoid extended down-time while batteries charge, flying with these cells may require several cells and a system that allows easily swapping charged and discharged cells in the plane. Of course, flying time is also considerably longer. It is now possible to get two or three moderately long flights from one charge. Safety is an issue with regular Lithium Ion batteries. They are encased in metal or plastic canisters and if charged or discharged (e.g., shorted out) to fast can explode, spraying hot Lithium around. The LiPoly cells are encased in a mylar "pouch". This means in the advent of a shorted out cell all it does is puff up and vent. Still care should be taken to insure an accidental shorting out between positive and negative terminals does not occur as your expensive investment in a LiPoly cell will be gone.

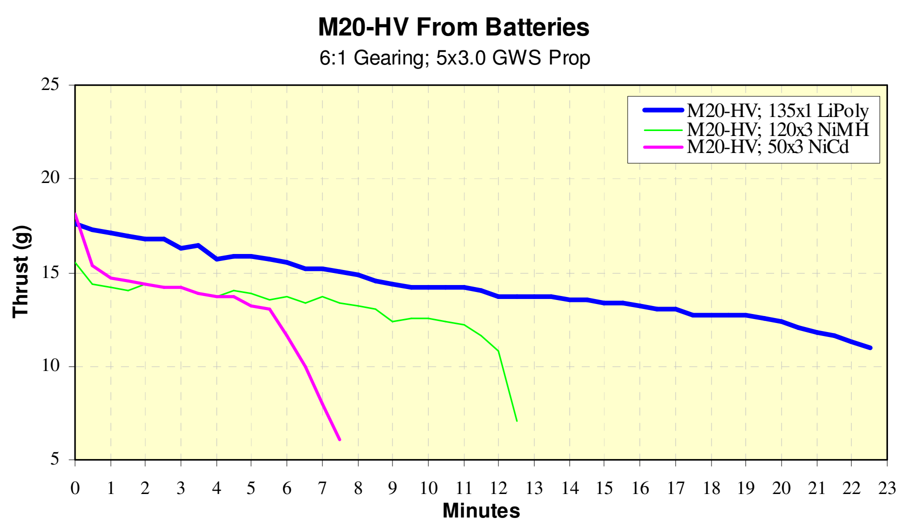
Static Tests

First, as previously noted, static tests should be taken with at least a grain of salt. In a static test the prop is not unloaded as it would be if the plane were moving through the air. This makes heavy reliance on static tests to pick prop and gearing combinations problematic. The appropriate solution is to test the various combinations in a well designed wind tunnel at various wind speeds as Dave Robelen has done and reported for a couple of motors here in RC Microflight. Wind tunnels for modeler use are very rare and I am not in possession of one. However, in this case we are focusing not on selecting a gear ratio and prop, but instead on comparing thrust and amps and volts from three battery sources for the same motor/gearing/prop combination — a combination that has successfully flown small models before. These tests are also for full power with a loaded prop. Actual amp draw will be less in flight. So, these tests represent a worst case scenario for the battery pack and results at varied throttle settings are likely to be better. Finally, static tests from battery packs can vary as much as 10% from test to test depending on how the pack peaked and other factors.

Now, let's look at some results. The two graphs show grams of thrust for LV and HV M20 motors over time from each of the three battery types. No receivers, ESC's or actuators were involved, just straight current from the battery pack to the motor. A quick comparison of the graphs shows that at full throttle the LiPoly cell dominates the other two cell types on thrust and on run time. The two graphs also show that the two motors are not equivalent. The LV motor, which has windings with lower resistance, generates more static thrust than does the HV motor. The Two Minute Mark Table gives various statistics at the two minute motor run point in the graphs. As can be seen in the Table, the static thrust from the LV compared to the static thrust from the HV motor is 22% higher for the LiPoly, 20% higher for the NiCd, and 8% higher for the NiMH.



This graph shows that the static thrust for the from the LiPoly cell is greater than from either a NiCd or NiMH pack, and duration is significantly longer as well.



This graph shows that for the M20-HV motor the static thrust from the LiPoly cell is greater than or equal to either the NiCd or NiMH. It also demonstrates that while the thrust from the M20-HV is lower than for the M20-LV, motor run times are significantly longer.

Two-Minute Mark Comparisons

	Thr(g)	RPM	Volts	Watts	Amps
M20-LV					
135x1 LiPoly	20.5	4,680	3.47	2.2	0.66
120x3 NiMH	15.6	4,200	3.28	1.7	0.53
50x3 NiCd	17.3	4,440	3.15	1.8	0.57
M20-HV					
135x1 LiPoly	16.8	4,320	3.77	1.4	0.38
120x3 NiMH	14.4	4,050	3.46	1.1	0.32
50x3 NiCd	14.4	4,020	3.36	0.9	0.28

For some applications people have sometimes preferred NiCd's over NiMH because the NiCd's provide slightly more thrust in the first couple of minutes of a motor run. Let's look first at the M20-LV test. The graph shows that the NiCd's do in fact generate more static thrust for the first few minutes than the NiMH's do. However, the LiPoly cell generates more static thrust than the NiCd's from the beginning of the test and maintains that advantage throughout the motor run. In contrast for the M20-HV test the LiPoly starts out generating about the same static thrust as the NiCd, but almost immediately begins to dominate it — although not by as much. What this indicates is that for higher amp draw applications the LiPoly will be able to provide more thrust for aerobatic maneuvers than can be achieved with a NiCd or NiMH. This can be seen more precisely in the Two-Minute Mark Comparison Table. At two minutes for the M20-LV the LiPoly cell is generating 18% more static thrust and putting out 25% more amps than the NiCd pack. For the M20-LV what this means is aerobatic performance for very light indoor planes is now possible. Over the next indoor season we will probably see many examples of this type of performance.

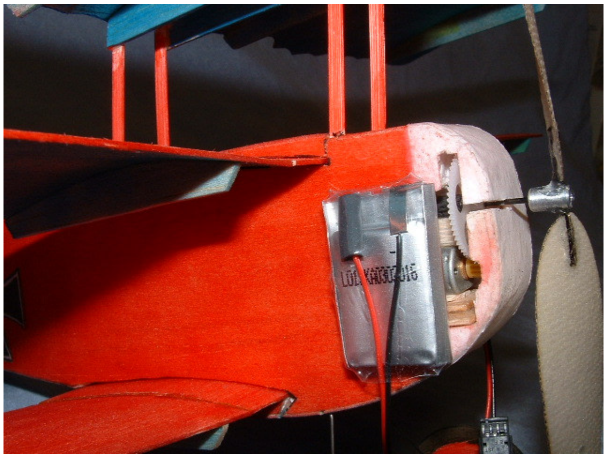
LiPoly Hookup

These cells don't look like the round NiCd and NiMH cells we are used to using. And, since they weigh so much less, alternate methods of attaching them are now possible. I chose to encase mine in light-weight clear shrink wrap from Airdyn to protect the delicate battery leads. I use the tiny JST plugs and wires for all my micro hookups and used the same for these cells so they are compatible with what I already have. I also decided to try mounting them with very small neodym magnets from Forcefield.com because of the batteries' light weight and to make attaching them easy in tight places. Eight 1/16x1/32 inch magnets (four on the plane and four on the magnet)weigh a total of 0.04g, which compares favorably to two pieces of velcro. I've found that inserting and removing velcro attached batteries in tight quarters inside a model can be difficult and may cause damage to the model. Since these cells take so long to charge, the technique sometimes used of leaving them permanently in the model and charging from some external means such as the landing gear legs would result in flights considerably far apart. This is another reason to make the battery easily removable. Of course, in some instances a very acceptable solution would be to wedge a LiPoly cell inside a fuselage with a piece of foam rubber.

From left to right, the steps I follow to make a single-cell LiPoly battery pack. (1) solder the leads onto terminals that have been brushed with electronics soldering flux; (2) tape the terminals with cellophane tape and fold back over top of cell and encase in clear shrink; (3) place magnets on template covered with wax paper and then glue to shrink wrap covering the cell.

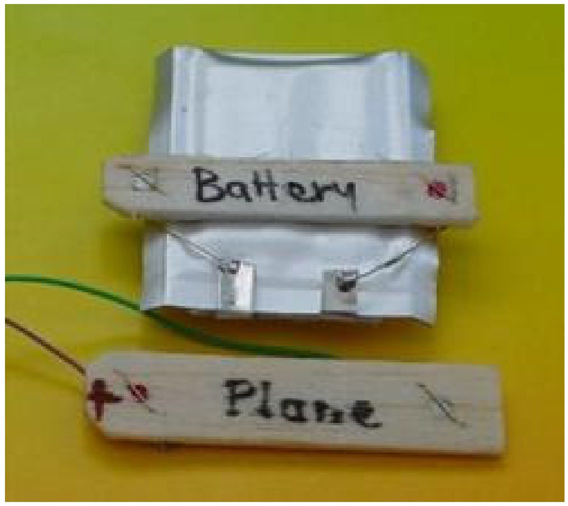
Kokam LiPoly cells in their standard form have an aluminum lead for the positive terminal, which is not possible to solder to. The cells can be ordered from the manufacturer with a Nickel tab affixed on the bottom side of the positive lead, which makes that side solderable. Be sure and check with your supplier to see if you can solder to both leads of the batteries you are purchasing. If the lead is aluminum, there are some alternatives to soldering including a conductive CA that FMA direct has indicated they intend to carry and a solder-like paste #ALP-21 from solder-it.com. My cells from Skyborn Electronics came with the Nickel tab. I brushed a small amount of electronics soldering flux on each terminal before soldering. A technique I got from Matt Keennon is to use a soldering heat sink clip from Radio Shack and clip it between the area of the terminal to be soldered and the battery. This helps prevent heat from migrating down the terminal and damaging the seal where it enters the cell. I soldered the positive wire to the bottom side of that lead (the side of the battery with no printing) and the negative wire to the top side of that lead. After soldering leads on, I bent the terminals back over the top of the battery, and then put a strip of cellophane tape over both leads continuing past the end of the terminal and around onto the bottom of cell. I put the tape on to make sure that nothing could contact the end of the pack and short between the terminals since the end of the pack is slightly open after encasing in clear shrinkwrap. The tape is also to help prevent the terminals touching each other and shorting out the cell. An alternate method developed by Skyborn Electronics is to apply heated glue from a glue gun or shoe goo to the soldered and folded back terminals to immobilize them and prevent shorting. Finally I encased the cell in light-weight clear shrink tubing from Airdyn.

I glued four small magnets on the back of the cell for mounting purposes. Since I wanted the packs to be interchangeable between planes, I made a small balsa jig to position the magnets the same place on each cell. I marked the spacing for magnets on a small sheet of 1/32 balsa, then drilled holes to accept magnets at each position, glued the magnets in with the poles all aligned in the same direction, and glued this to 1/8 balsa with the grain going the opposite direction, and then added a strip of balsa along one side to aid in aligning the cells consistently (see picture). The assembly procedure is to place a small piece of wax paper over the jig and then put a magnet on each magnet on the jig, with the wax paper separating them. This insures spacing of the magnets and also that the poles of the magnets are aligned in the same direction. With a toothpick, apply a drop of medium CA on the top of each magnet, place the shrink-wrapped LiPoly cell bottom side down on these cells and hold for a minute or so. After the CA has hardened, the battery can be removed. To place corresponding magnets on a model, put the wax paper on the back of the battery, put a magnet on each of the magnets glued to the back of the cell, apply a drop of CA, and then hold the magnet against the model where you want the battery to be mounted. Once your template is made, you should be able to attach LiPoly cells to any of your models and swap as required.



Here the LiPoly cell is mounted with magnets in a vertical position on the outside of a semi-profile fuselage on my Fokker Dr1 triplane. The Dynamics Unlimited receiver is mounted on the opposite side of the fuselage. The cell could also be mounted with magnets inside a fuselage.

For extremely light indoor planes intended to fly very slowly and with low wing loadings, every fraction of a gram is important. Didel in Switzerland is oriented primarily toward this type of indoor plane. To this end they have developed an alternate mounting technique. In their method thin wires soldered to the battery leads are threaded across a pair of magnets embeded in a balsa strip which is glued to the LiPoly cell. The magnets are oriented with poles in opposite directions so the cell can only be attached the correct way. Wires from the motor run to a corresponding balsa strip — which is glued to the plane — and threaded over its corresponding magnets. The Didel method reduces the weight added by shrink wrap and heavier wire and a plug, and contact is made and maintained magnetically. In the event of a crash the LiPoly cell can be knocked completely free. Of course, since there is no protective shrink wrap or cellophane tape, care must be taken to not inadvertently short between the exposed terminals. A mounting plate similar to the one on the plane can be constructed to be plugged into a charger and serve as a docking system for charging the cells. In addition, if people who fly together standardize the spacing between the magnets, LiPoly cells can be swapped between various models. More details on this method can be found at http://www.didel.com.



Didel's mounting method for very light indoor planes uses neodym magnets to both hold the battery in place and make electrical contact.

Charging the 135mAh LiPolys

Charging LiPoly cells is not like charging "your father's" NiCd's or NiMH's, and in fact chargers for those cells will not work with LiPoly cells under any condition. Special chargers for lithium cells are required. Be sure and ask the vendor you decide to purchase a charger from whether it will work with LiPoly cells as well as Lithium-Ion cells. Most of the lithium-ion chargers I have heard of seem to work, but checking is a good idea. The charging cycle for a LiPoly cell consists of three stages: (1) precharge, (2) constant current, and (3) constant voltage. Charging a LiPoly cell at a higher rate like 1C can damage the cell when the cell's voltage is relatively low. So, the precharge state is at a lower charge rate. Some chargers like the Maha charger can also put on a "surface" charge during this time to automatically determine how fast the cell can be charged. In the constant current part of the cycle a constant current generally equal to the cell's capacity (i.e., 1C for a "fast" charge) is put into the cell until its voltage reaches 4.2 volts. Next, in the constant voltage section of the cycle, a current is put into the cell to maintain its voltage at 4.2 volts and the current is gradually reduced until the current going in drops below 1/10 of the 1C charge rate, at which point the charge cycle is completed. Accuracy is important because deviations very much above 4.2 volts can permanently damage the cell and reduce its capacity. Charging at greater than the 1C rate can also damage the cell. And, finally, charging at too fast a rate during the precharge stage, when the cell's voltage is lower, can damage the cell.

I purchased the Maha C777Plus charger from Skyborn Electronics. This is a "high-end" charger that can charge LiPoly as well as Li-Ion, NiCd, and NiMH cells. There is a switch on the side of the charger that selects between Lithium or NiCd/NiMH charging. It also has a LCD display for amps put into the cell, voltage, and time. This charger can also operate either straight from 120v AC current or 12v DC current, automatically detects the capacity of the cell or pack being charged, and, can charge up to a 4-cell LiPoly pack. The charger also has sophisticated circuitry to detect and prevent overcharging a cell whose capacity and characteristics have changed either through normal use or abuse. I label all my battery packs with a label maker and keep a log on each one. Because of all these features I was willing to pay the higher price for the Maha charger since it allows me to monitor the charging history of my LiPoly cells to see if the capacity has decreased. And, with this charger I will be able to charge larger cells and multi-cell packs as I progress to them in the future.

Bob Selman has designed a charger specifically for a single 135mAh LiPoly cells that incorporates all three of the steps in the charging cycle. Best of all, it only costs $25 and is very small. I have a number of NiCd/NiMH chargers from Bob and have been quite happy with them. Although I have not used his LiPoly charger, I know several people who have and they are all pleased with its performance. Bob's charger uses a 12v power source and charges a single 135mAh cell. A LED charge status indicator tells when the cell is fully charged.

Shown on the left is the Maha C777Plus universal charger, from Skyborn Electronics. It includes a temperature sensor probe and automatically determines the number of cells and charge rate. It can charge up to 4 cells and works from either 120v AC or 12v DC sources. It also has a display screen that tells charge time, amps, and volts which are useful for monitoring your cells' charging history. Shown on the right is the Bob Selman Designs charger which was specifically designed for the Kokam 135mAh cells. It uses a 12v power source and charges a single cell. A LED charge status indicator tells when the cell is fully charged. It is simple to use, accurate, and cost effective at $25.

There are other sources for chargers than just the two I've mentioned here. See the list of sources for these LiPoly cells and chargers. There will undoubtedly be many more chargers coming on the market in the coming months. There will also be more sources to buy these cells. However, these are the vendors selling them at the time this was written.

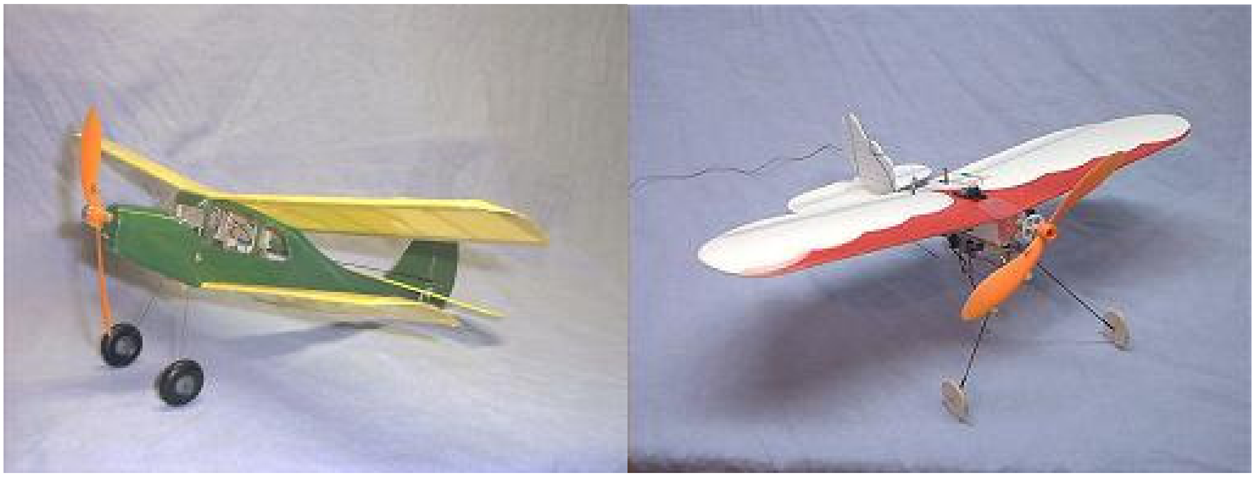
Sources of 135 mAh LiPoly Cells and Chargers

Vendor	Web Site	Products
Bob Selman Designs	users.joplin.com/~bselman	cells & charger
Dave Lewis	homefly.com	charger
Dynamic Web Enterprises	smallrc.com	cells
FMA Direct	fmadirect.com	cells & charger
Graham Stabler	indoor.flyer.co.uk	cells
Ruijsink MicroMag	ruijsink.nl/mm_hoofd.htm	cells
Skyborn Electronics	bktsi.com	cells & charger
Wild RC	wildrc.com	charger

Two-Cell Applications

I've concentrated on single cell LiPoly applications in this article. However, I've recently begun using them in 2-cell packs in non-actuator planes. Some time back I built a Punkin II from Dave Robelen's plans in RC Microflight. Unfortunately, with a 4-cell 120mAh NiMH pack it weighed in at 56 grams compared to Dave's at 48 grams. The best I could achieve was one lap around a basketball court, requiring full throttle to barely sustain level flight. Switching to a 2-cell 135mAh LiPoly pack dropped the weight to 52g. But the power increased to the equivalent of a 7-cell NiMH pack. Now my Punkin ROGs, has power to spare and quite long flight times. This is an example of how LiPolys can save a model that was built too heavy. The equipment I'm using in the Punkin is Mabuchi N20 low-volt in a Kenway 4.2:1 gear drive with a GWS 6x5.0 prop. Receiver is the Sky Hooks & Rigging hybrid receiver/ESC with the BEC set to 6.0v, a perfect setup for a 2-cell LiPoly pack. Servos are Westechnik 3.0 linear servos.

The other plane I've used a 2-cell LiPoly pack in is a 15-inch wingspan stick sort-of Gee Bee. I built this from 3mm Depron foam specifically for use with LiPoly cells. It uses a Sky Hooks & Rigging RX72 receiver, a JMP HF9 ESC, and GWS Pico servos. Propulsion is via a N20 low-volt motor geared 6:1 with Didel 60t spur gear and Kenway 10t pinion and a GWS 6x5.0 prop. AUW is 48g, and performance is spirited as a result of the ailerons. With just 74 square inches of wing area the wing loading is 3.3 oz./square foot. Prior to the availability of LiPoly cells this plane would have had too high of a wing loading to be practical and is just one example of what is now possible with 2-cell 135mAh LiPoly packs.



Left: My Punkin II bipe built from Dave Robelen's RC Microflight plans became a successful plane only after a 2-cell 135mAh LiPoly pack was swapped for a 4-cell 120mAh NiMH pack.

Right: My 15-inch span stick Gee Bee built from 3mm Depron specifically for a 2-cell 135mAh LiPoly pack would not have had a flyable wing loading without a 2-cell LiPoly pack.

Flying

What can be said about flying with these cells except that everyone who trys them gets a huge grin on their face. These cells make micro planes that we've dreamed about possible because of their light weight, capacity, and high discharge rates. Not only that, but they are sure to be the savior of many planes what were built a little to heavy and just didn't perform with two or three-cell NiCd or NiMH packs. Putting in a lighter battery turns out to be easier than building light.

Since for most single cell LiPoly applications, there are no ESC's with a BEC circuit to reduce power to the motor when the voltage declines below 3.0 volts, for now you need to be more careful. I take an Astro Micro Meter (but a simple multi meter will do) with me when I fly. I land part way through a battery's discharge, unplug it, and test its volts. If the volts are not close to 3.0 yet, I put the battery back in and fly again. After a few flights you develop a feeling for how long the cell will last given your application and how you fly. Other than this consideration, flying with these cells is just one big grin.