The huge King Crimson aptly demonstrates how a large plane can be flown on modest electric power.

The Black Baron is a replica of Bill Barber's famous airshow Stearman.

A collection of motors and speed controllers. Left to right: Astro Flight's 90, 25, geared 15, and the Keller 25 and 50. Front: the Astro 207, Jomar SM-4 and Jomar Maxcell speed controllers. Top: the Aveox "brushless" motor and special controller.

Probably the most advanced fighter of WW II, the German Horten IX flying wing was developed too late to see action. This ducted-fan model uses twin, homemade $2\frac{5}{8}$-inch rotors turning at 32,000rpm to create 48 ounces of thrust.

Charging Into Electric Flight - Keith Shaw - Radio Controlled Sport Flying (from the publishers of Model Airplane News) - January 1994

WHILE THERE ARE a multitude of ways to power a model airplane, I believe that electric power offers several outstanding advantages. Even though the most often quoted features are cleanliness and minimal noise, the real advantages are reliability, reproducibility and versatility.

An unreliable power system is the most common frustration that defeats would-be modelers. With electric power, there is no cranking a balky engine, fiddling with needle valves too near a whirling meat slicer, unreliable idles or blown glow plugs. Gone are the worries of tank location, pinholes in the fuel lines, structural degradation from oil soaking, vibration-induced radio failures and equipment aging. Instead, you just position your plane on the taxiway, advance the "throttle," taxi out and take off! The power from an electric is so reproducible that if you can do a 20-maneuver acrobatic routine when the plane is new, five years later, you will still be able to do the same routine, summer or winter, rain or shine.

Electric power is also very versatile because the motor is a variable horsepower device. By varying the size of the prop, the number of cells, and the use of a gearbox, it is possible to use a single motor to power everything from a "fluffy" hand-launched sport plane or gentle glider, to a vertical climbing "skyrocket" sailplane, 120+ mph pylon racer, potent acrobatic ship, or a large scale plane.

From an aesthetic (and aerodynamic) standpoint, the awkward model-engine cylinder, muffler and plumbing spoil the look of a clean sport model or a painstakingly detailed scale model. With electric power, a clean, streamlined nose or exact scale cowl is easily done. Many projects that are usually considered tough or impossible become easy, or at least feasible. Twins and multi-motored aircraft are almost trivial, as problems of synchronization, single-engine failures, cramped nacelles, and structural nightmares are nonexistent. For a complete discussion on this topic, see my "Electric Twins" article reprinted elsewhere in this issue.

Pusher configurations invariably suffer the problems of overheating, fuel flow, muffler interference and balance. When using electric power, only a small motor would be mounted in the tail, while the battery pack is positioned in the nose,

The graceful deHavilland Comet was designed for long-distance racing.

eliminating the need to add lead to get the correct balance. There would be no need for pusher props (or, more correctly, left-handed props), as most electric motors can be made to run in either direction.

The easy addition of gearboxes enables an electric motor to turn very large, efficient propellers with modest horsepower. Many scale models of radial-engine aircraft do not need extreme levels of horsepower, just a sensible amount efficiently coupled into a propeller large enough to clear the cowl. With glow power, a grossly oversize engine is usually needed just to get a little bit of prop beyond the edge of the cowl. Even the smaller geared motors can turn 12- to 14-inch props.

If all this sounds attractive, electric power may be for you. But before you buy some used equipment at the next swap shop and throw it into your old fuel-soaked "Belchfire 60," please read on. A little introductory information can save you from some expensive, discouraging mistakes.

THE FOUR KEYS TO SUCCESS

When approaching a new challenge such as electric flight, a carefully considered plan of action will minimize frustration and maximize results. First, **set an achievable** goal with several measured steps to reach it. If your dream is to fly an electric B-17 or a WWII fighter and you are presently flying a basic glow-powered trainer, there will be *many* steps! Don't expect to learn everything at once. Even if you have well-developed flying skills, I would still recommend starting with a sport electric plane just to get used to the technology of charging Ni-Cd (short for nickel-cadmium) batteries, maintaining electric motors, optimizing prop selection and building structures appropriate to the task. Even after flying R/C for over 30 years, I still build "test-bed trainers" to check out an unconventional aerodynamic layout or bizarre configuration. These test-bed aircraft have the desired configuration, size, wing area and power system but use simple structures and no "fancies" such as retracts. I practice flying the test-bed until I'm comfortable with it, then start ballasting it up to what a serious version might weigh. This way, I'm not fighting all the battles at once.

Second, **invest in good equipment**. There is an old adage, "Buy cheap, buy twice." Trying to get away with cheap car motors; old, questionable Ni-Cds; or an oil-soaked glow airframe are ways of guaranteeing failure. The logic goes something like this: everyone in the club tells him electrics won't fly, so he'll use an old ARF picked up at the last swap meet, a car motor that was in the "half-off" bin at the hobby shop, some batteries out of a discarded Dustbuster and the oldest radio with the big servos. In front of the waiting club members, it settles slowly into the weeds and/or burns up the motor, thereby *proving* that electrics can't fly! While you certainly don't have to buy the "Rolls-Royce" equipment (with a price to match), I do heartily recommend buying equipment that will last. Many times, a very powerful, sophisticated cobalt motor will be less than twice the cost of a inexpensive sport motor, but will last 10 times as long. The same goes for Ni-Cds, chargers and speed controllers.

Third, **concentrate and do the best job you can on your project**. "Good enough" has no place in this hobby! A straight, accurately built, balanced and trimmed airplane has much less drag, is easier to fly and will perform better with less power. Be proud of your skills, and performance will be your reward.

Finally-practice, practice, practice! While virtually everyone will imagine I'm talking about eight-point rolls or Lomcevaks, it is more important to learn to *land* correctly every flight. Careful landings dramatically reduce the structural loads and weight requirements of the airframe. Fifty percent of the weight in a typical glow-powered airplane kit is just there to allow it to survive the occasional "hard landing." You've seen them: the pilot lands about 3 feet high, the plane stalls, drops a wing tip, cartwheels two or three times, flips end-over-end and lands on its back. And the pilot is really mad that he broke another @#~(!% prop!

Once the hard landing barrier has been overcome, the structural weight can be reduced to a point where the total flying weight may actually be lighter than a glow plane of similar performance, while maintaining every bit of the aerodynamic strength. Learning to fly efficiently will also improve the performance and extend your flight time. The single most power-consuming maneuver is gaining altitude. Random climbing and diving or "horsing" the plane around the sky will lead to shorter flights. Climb to a comfortable altitude and base your aerobatics and circuits relative to this reference line. Smooth flying, rudder finesse and power management can easily double your flight times.

START READING

There is a lot of new information and techniques that will be invaluable to your quest after reading this short primer on electric power. Probably the best, most up-to-date sources are the electric columns in most magazines. If you don't have or keep back issues, check with your club members or the local library. Bob Kopski writes air excellent column for *Model Aviation*, and Mitch Poling wrote for *Model Builder* for more than a decade (of course, Mitch and I now share a column in *Model Airplane News*). You will notice that these columns have a lot of "meat" to them, not endless lists of contest results, smudged photos, or gossip. I guess it wouldn't hurt to plop a couple of my articles "Electric Sport Scale" in *Model Builder*, July 1987, and "Electric

Even the infamous Gee Bee-R1 flies well as an electric, partly because of the near-scale diameter propeller.

Twins" in *Model Airplane News*, December 1991, reprinted in this issue. Both articles deal with the actual design techniques involved with choosing a suitable airframe-motor-battery system for a desired project. This article will concentrate more on the introductory material, with recommendations to ease you successfully into electric flight.

The Percival Mew Gull was the 1934 winner of the British King's Cup Race and represents the height of streamlined efficiency.

THE HARDWARE

The main components of an electric-power system bear a recognizable similarity to those of a typical fuel-powered one. The propeller is turned by the engine (motor) while consuming fuel (current) from the tank (Ni-Cd battery), while the system power is varied by a servo-driven carburetor (speed controller). The tank (Ni-Cd pack) is filled (charged) by transferring fuel (current) from the jug (12V auto battery) using a pump (charger).

I'll try to give a short description of each of these elements and explain some buzzwords.

MOTORS

The electric motors that we use can be anything from inexpensive, mass-produced industrial units to exquisite, nearly handmade masterpieces. In America, motors are referred to as "ferrite" or "cobalt." This indicates the type of magnet material used in the motor. While magnet material alone does not ensure quality, it indirectly does.

Samarium-cobalt is a rare earth alloy with a very high magnetic field strength, and it's extremely expensive and virtually impossible to machine or shape. The manufacturers of high-performance cobalt motors always "throw in" instrument-grade hall bearings, large replaceable silver brushes and rugged case parts machined from bar stock. Astro Flight*, Plettenberg* (Ultra and Hectoplett) and Robbe* (Keller) all make excellent cobalt motors, although the Astro Flight motors are less than half the cost and have every bit of the performance. I have cobalt motors with hundreds of runs that are more than 10 years old and, except for new brushes every 4 to 5 years, I have never taken them apart. The performance is the same as when they were new. While motors should be rated by wattage (horsepower) and nominal operating voltage, most hobby manufacturers use alternate identification systems that I believe are less useful. Astro Flight makes an attempt to simplify motor ratings by assigning a number that indicates the equivalent performance of a sport glow motor. Therefore, a direct-drive cobalt 40 motor would run the same prop at a speed comparable to that of a glow .40-size engine. However, with the addition of a gearbox, the performance more closely mimics a 4-cycle engine of the next larger size, i.e., a geared 40 motor is comparable in performance to a 4-stroke .65 glow engine.

Ferrite motors use a barium ferrite magnetic material that is cheap to make and easily formed. These motors can be anything from very simple can motors with a formed sheet-metal case, bronze sleeve bearings and non-replaceable brushes to relatively sophisticated motors that feature ball bearings, replaceable brushes and adjustable timing. While cobalt magnets are virtually indestructible, ferrite magnets lose their field strength owing to use and abuse. Ferrite motors are all right for low-powered sport planes, but in my experience, they rarely last more than one season in any performance environment (say a 100 or so runs at 150 to 200 watts on a 05 frame motor). Most ferrite motors have tiny brushes and small-diameter commutators that wear badly at high power levels and need frequent maintenance.

Some exotic European motors use a magnet material known by the trade name of "Neodym," which is a neodynium alloy. While Neodym has a higher field strength than samarium-cobalt, its field rapidly diminishes at elevated temperatures. These motors are powerful, but are designed primarily for short bursts (10 to 20 seconds), such as those employed to boost a glider to thermalling altitude. During the glide phase, the motor magnets can cool off until the next climb.

A new class of high-powered motors for aircraft are called "brushless," like those made by Aveox*. These have the permanent magnets mounted on the rotating shaft, while the stationary windings are on the inner wall of the motor shell. A specially made controller turns these windings on and off in such a way as to make the shaft rotate. While these motors are more expensive, mostly owing to a vastly more complex controller, they do have some real benefits. Lack of brushes eliminates the major mechanical wear point and minimizes radio interference. The switching transients at the conventional brush-commutator cause a lot of electrical noise that can degrade the radio-link reliability. The brushless motors are more efficient (typically 10 to 15 percent) since there is no brush loss and lower ripple current. I think the future of very high-power electrics (above 1hp) will be with brushless motors.

NICKEL-CADMIUM BATTERIES

The fuel tank for an electric is an assembly of rechargeable nickel-cadmium cells (Ni-Cds). The no-load voltage of a single Ni-Cd is nominally 1.2 volts, which is why the car crowd labels a 6-cell pack as 7.2 volts. But under the current loads commonly used in electric flight, the voltage delivered to the motor is about 1 volt per cell. The size of the Ni-Cd is the cell capacity, measured in amp-hours (Ah) or milliamp-hours (mAh). A 1.0Ah

The Zlin 526 was the Czechoslovakian aerobatic plane that first performed the Lomcevak

This Battle of Britain Spitfire has more than 500 flights on it—a testimony to the reliability of electric power.

cell would deliver 1.0 amp into a load for 1 hour, 10 amps for 6 minutes (1/10 hour), or 30 amps for 2 minutes. However, the more important characteristic of a Ni-Cd is the output impedance (also known as the internal resistance). If we imagine the Ni-Cd as a bottle that holds electrical energy, the cell capacity would be the volume of the bottle, and the internal resistance would be the size of the mouth. Poor-quality Ni-Cds have a small "mouth," so it is difficult to get the energy to the motor at the rates we need for electric flight. Suitable Ni-Cds have very low resistance, typically 3 to 5 milliohms, and can efficiently supply 70 to 80 amps to the motor if needed. My preference is the Sanyo "R" type cells, such as the 600SCR, 800AR, 1000SCR and 1400SCR (*and now 1700SCRC km*). They are efficient, reliable and tolerant to mild overcharging and other types of abuse. If you wish to make up your own battery packs, an article I wrote for *Model Airplane News*, August 1993, should explain the techniques. If you would rather purchase assembled packs, SR Batteries* makes excellent ones in almost any size, capacity and configuration imaginable.

Many people are waiting for the magic, feather - weight, high-capacity cell to arrive before entering electrics. I believe it will be a long way into the future. I try to keep abreast of battery technology in the scientific literature, and all the hoped-for "saviors" have some pretty severe drawbacks. Most of these new "alternative chemistry" cells have improved capacity but very high internal resistance, sometimes 20 to 30 milliohms or more per cell. This would limit usable current drain to a few amps, and you would have to carry over 100 cells to get enough horsepower for any kind of performance. Some of the new cells can only be slow-charged, while others can only be fast-charged while monitoring some very subtle parameters that would not be practical in the field. Furthermore, several of the high-tech cells involve some absolutely deadly chemistry not suitable for home (or airborne) use. No alternative power cell can be charged as easily, safely or reliably as a Ni-Cd.

POWER CONTROL

One of the real advantages of electrics is the efficient, accurate control of power. Since good motors can stand very high powers for short times, the plane can be propped for the highest power demand, such as a vertical roll or vertical 8, and flown at reduced power for the remainder of the flight. Of course, for the simplest airplanes, a servo-operated switch or relay device would be OK, but larger systems need a variable power speed controller. Some of the larger motors could literally rip the front end off a plane if they were "hard" started by an on/off switch, so a "soft-start" circuit smoothly applies the power.

All solid-state speed controllers use the technique of duty-cycle, pulse-width modulation. The motor is pulsed with full battery voltage at various on/off ratios to achieve intermediate power levels. The solid-state switching element is called a "Mosfet" short for "metal oxide semiconductor field-effect transistor" (just in case you really wanted to know). Most of the low-cost controllers use a low switching frequency of about 50Hz derived from the receiver decoder clock. These speed controllers are all right for low-performance use, but they're very inefficient at partial throttle, making the motor run very hot. The better speed controllers use high-rate switching. usually around 2000Hz, and are virtually 100-percent efficient over the entire power range. For example, a motor operated at half power would run twice as long.

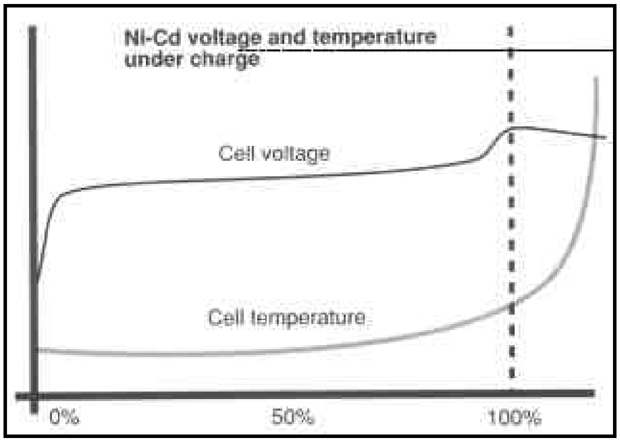
Another important feature to look for is "optical isolation," which physically breaks the electrical path between the power system and the receiver. Electrical noise generated by the motor (and sometimes by the switching section of the speed controller) can scramble the radio or severely reduce range, causing glitches or possibly a crash. A BEC (battery eliminator circuit) can actually pipeline motor noise right into the receiver! I do not use or recommend a BEC for anything but the tiniest of electrics, i.e., less than 50 watts and 16 ounces flying weight. Saving the weight of a 1- or 2-ounce receiver battery pack is not worth the added risks of failure. Use a 50mAh to 270mAh pack on small planes and field recharge it if necessary. If you insist on using a BEC, please be careful to time your flights. I have seen far too many planes lost after long thermal flights that depleted the remaining power in the motor battery. When that happens, the radio stops working, and a fly-away or crash results.

There are many other specialty features available, and I might try to cover them in a future column but, for the record, I use Jomar* (SM-4 and Maxcell) and Astro Flight (203 and 207) speed controllers. They have proven to be rugged, reliable and well-made.

CHARGERS

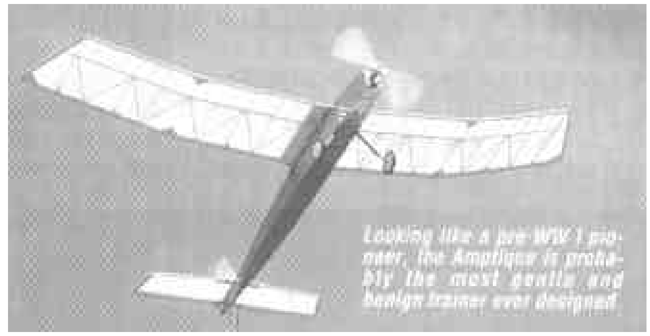
Chargers can range from simple units costing $20 to $30, up to sophisticated precision devices reaching several hundred dollars. To help explain the variance, the different techniques for charging must be discussed. The simplest chargers use the timed charge method, where an empty pack is charged at a certain current for a fixed time chosen to not overcharge the cells. As an example, if a discharged 1.2Ah pack were charged at 4 amps for 15 minutes, the cells would be nearly full, having received 1.0Ah of energy. For sport use, this would give a flight somewhat shorter than ideally possible, but perhaps sufficient for the modeler's use. These chargers usually have a meter, some sort of clock timer and perhaps even a current adjustment feature. The biggest drawback to them is that they can, at most, charge 7-cell packs from a 12V car battery, and sometimes not even that well. Today, there are many chargers available for only a few dollars more that incorporate a "boost" circuit that creates a higher voltage source to charge a higher number of cells. Some go all the way up to 36 cells!

For maximum performance, it is desirable to get a full charge on the cell without risking overcharging. Severely overcharging a Ni-Cd is the worst thing you can do to it. The cell will get *very* hot, and increased internal gas pressure might blow the safety seal that prevents explosions. Fortunately, as a Ni-Cd approaches full charge, several measurable things happen: the cell temperature will start to rise, and the cell voltage will increase to a peak value and start to decrease (see figure). Properly monitored, a reasonable temperature rise is a



viable way to determine end of charge; in fact, virtually all rechargeable hand tools rely on this technique. The main drawback is that a temperature sensor must be in contact with the battery pack, which would mean a four-wire connection to the charger.

The characteristic voltage signature has become the standard detection scheme for electric flight. During most of the charge cycle, the pack voltage will rise very slowly, but at about 95 percent of full charge the voltage will begin to rise faster. At the 100-percent charge point the voltage reaches a maximum value and very slowly starts to drop. The actual value of the peak is not important, as it is a function of number of cells, cell temperature, charge current and phase of the moon. This voltage retrograde could be monitored with a digital voltmeter and the charge manually terminated, or some fancy electronics can be included in the charger to do this automatically. There are quite a few of these peak chargers on the market. There are now so many excellent peak-detection-boost chargers out that I can't recommend any of the low-level 6- to 7-cell chargers. For only a few dollars more you get a good charger to grow into in the future. I highly recommend the Astro Flight 110XL (*replaced by the 110D km*) and 112PK (*replaced by the 112D - which Keith now uses km*), SR Smart Charger and the TRC* Engineering IV and VI. A quick addendum concerning the charge source is in order. The most common one is the 12V starter battery in your car, and if it is in good condition, it will work fine, Otherwise, you might find yourself stranded at the field at the end of a great day of flying! If you wish to cart a separate battery to the pit area, choose at least a 40Ah unit (a medium-size auto battery). Trust me, motorcycle or garden tractor batteries will not work for very long. I have also had very poor performance from high-capacity gel-cells. Probably the best choice is a deep-cycle, marine/RV battery, such as the Sears Die-Hard no. 96493. Mine is more than four years old and still going strong.



Looking like a pre-WW I pioneer, the Amptique is probably the most gentle and benign trainer ever designed.

TRAINERS

While almost all trainers are designed for 6 cells and a servo-driven on/off switch, the use of 7 cells and an efficient, high-rate speed controller allow better climb performance and greatly extended cruising times during training.

° **Goldberg* Mirage** will fly OK with the supplied motor on 7 cells, but is much better with an Astro geared 05 (the landing gear would have to be extended). I would also recommend increasing the dihedral to improve the rudder response.

°**Amptique** re-released by Spirit of Yesteryear Model Aircraft*. Probably the most benign trainer ever designed, it will fly well on any geared 05 and on 6 or 7 cells.

°**PT-Electric** (Great Planes*) is one of the few trainers in recent times with sufficient dihedral. It will fly well with the supplied motor on 7 cells, but only use 1/4-inch washout in the wing. The huge recommended washout will cause excessive drag and drastically reduce the climb margin and flight time.

BIG TRAINERS/SPORT

°**Sig* Seniorita** one of the few glow kits that converts well to electric. Bob Kopski wrote an excellent conversion article for *Model Aviation*, July 1991. Use an Astro cobalt geared 25 and 14 or 16SCR 1400mAh cells. (*1700SCRC cells would be the choice today, since they weren't available when this article was written. km*).

° **Sig Senior Kadet -** use an Astro cobalt geared 40 on 18 or 20 SCR 1400mAh cells (*see note above km*). I think both these airplanes fly better as tail-draggers, but that view is probably clouded by my dislike of nose wheels!

OLD-TIMERS

Old-timers make excellent trainers, but are somewhat harder to build. If you have experience and enjoy building stick-and-rib structures, try one.

° **Astro Viking -** use a Astro cobalt geared 035 on 6 SCR 1000mAh cells, or a geared 05 on 7 SCR 1000mAh.

° **Playboy and Lanzo Bomber -** re-released by Spirit of Yesteryear Model Aircraft. Both fly well with a geared 05 on 7 SCR 1000mAh cells.

GLIDERS

This is a tough one, as there are literally dozens of excellent electric sailplane kits ranging from lightweight gentle floaters to heart-stopping gonzo machines with measured climb rates of more than 5,000 feet per minute! You might want to browse through the Hobby Lobby* catalogue to get an idea of what is available. They also carry a very wide range of electric kits, motors and associated products. I have also been particularly impressed with the quality and performance of the Falcon 550E now marketed by Airtronics*.

AEROBATICS

The development of a truly competitive electric F3A pattern machine is still a little way off, but most sport modelers wouldn't be interested anyway. However, electric power can provide the level of aerobatic performance seen at most club fields.

° **Great Planes Electrostreak -** quite aerobatic, even with the supplied ferrite motor, but amazingly agile when powered by Astro 15 on 10 SCR 1400mAh cells with a Jomar SM-4 speed controller. The fuselage needs to be slightly modified for this (and some cosmetics on the ugly nose wouldn't hurt), but it is probably the best hand-launched aerobat on the market today. Any maneuver you can think of can be done if you have the skill.

° **Today's Hobbies* Skyvolt -** Bob Kopski's design is an excellent sport aerobatic plane on anything from an Astro 05 or 15, direct or geared. This would be a good choice if you require ROG, but if is not quite up to the 15-powered Electrostreak. Still very capable of inside and outside loops, rolls, point rolls, all spins and snaps, rolling circles, etc.

SCALE

There have been several very successful electric scale planes at national competition levels, but the following are some entry-level, stand-off-scale designs to get you started.

° **Great Planes Cub -** stand-way-off model of the ubiquitous Cub, it's very marginal with the supplied motor; however, it flies quite nicely on an Astro geared 05 and 7SCR 1400mAh cells. Several people in this area prefer using an Astro 15 direct drive on 10SCR 1400mAh cells and an 8x6 prop.

° **Astro Flight Porterfield Collegiate** (*unfortunately no longer kitted, but some can still be "found" as of 7/96 km*)- 6-foot light plane that is not a Cub! It is available packaged with a geared 25, a motor mount and a 13x8 prop. Typically, 14 SCR 1400mAh cells are used, which give if long flight and some of the most realistic touch-and-goes you've ever seen.

° **Concept* Models Fleet Bipe -** designed for an Astro geared 40 and 16 to 20 SCR 1400mAh cells, it's quite aerobatic while maintaining docile handling characteristics, and it looks great in the air or on the ground. Everyone should already guess I have a real weakness for radial-engine biplanes!

CLOSING THOUGHTS

Even though this is an introductory article, I have included several photos and relevant information on some advanced electric aircraft to whet your appetite and help convince you that electric flight is a viable, mature field of modeling. Come and join the quiet future! If you have any questions, you can write to me. Please don't forget the courtesy of a self-addressed, *stamped envelope*. Keith Shaw, 2756 Elmwood, Ann Arbor, MI 48104.

The Messerschmidtt M35b was a 1930's German aerobatic champion flown by Willi Stor.

About the Author

Keith Shaw is one of the foremost electric-flight modelers of our time, and his beautiful, scale, electric models have appeared frequently in the modeling press. Keith has been fascinated (some would say obsessed) with flying machines his entire life. After starting with free-flight and control-line models in the early '50s, Keith entered the world of R/C modeling around 1960 using homemade, vacuum-tube radio equipment. In 1975, while competing in pattern, scale and pylon, Keith became interested in electric flight. This interest has since grown to dominate his time. He flies in several dozen air shows each summer to demonstrate the advantages of electric flight.

Keith in a senior research scientist at the University of Michigan, where he develops exotic instrumentation to study molecular structure. In his remaining "copious spare time," he enjoys rock 'n' roll and an occasional few hours of sleep.

Here are the addresses of the companies mentioned in the article:
Astro Flight, Inc., 13311 Beach Ave ., Marina Del Rey, CA 90202.
Plettenberg; distributed by Hobby Lobby International, 5614 Franklin Pike Cir., Brentwood, TN 37027.
Robbe Model Sport, 170 Township Line Rd., Belle Mead, NJ 08502.
Aveox, Inc., P.O. Box 1287, Agoura Hills. CA 91376-1287
SR Batteries Inc., P.O. Box 287, Bellport, NY 11713
Jomar Products Inc., Div. of Electronic Model Systems Inc., 22482 Mission Hills La., Yorba Linda, CA 92687
TRC Engineering, 0-10972 10th Ave., Grand Rapids, MI 49509
Cart Goldberg Models, 4734 West Chicago Ave., Chicago, IL 60651
Spirit of Yesteryear, 40 Holgate St., Barrie, Ont. L4N 2T7, Canada, (705) 737-0532
Great Planes Model Mfg., P.O. Box 788, Urbana. IL 61801
Sig Mfg. Co., 401 S. Front St., Montezuma, 50171
Hobby Lobby International, 5614 Franklin Pike Cir., Brentwood, TN 37027.
Airtronics Inc., 11 Autry, Irvine, CA 92718.
Concept Models, 2906 Grandview Blvd., Madison, WI 53713; (608) 271-5678

Data on Keith Shaw's Electric Scale Air Force is on the following page:

Keith Shaw's Electric Scale Air Force

Aircraft	Scale	Span (Inch)	Area (sq.in)	Weight (lbs)	Motor (cobalt)	Number of cells	Sanyo cell type	Motor control	Wing loading (oz/sq.ft.)	Power loading (watts per lb)	Special features
Spitfire Mk. 1a	1/7.2	62	670	6	Astro 40g 12x8 Rev up	20	SCR 1.2 Ahr	Jomar SC-4	20	70	mechanical retracts Merlin “sound”
deHavilland Comet "Black Magic"	1/6	88	900	8½	Twin Astro 25 direct 9x7 Rev up	28	SCR 1.2 Ahr	Astro 205	22	66	Rhom-Air retracts
Gee Bee R-1	1/6	50	400	5½	Astro 25g 14x9 Rev up	14	SCR 1.2 Ahr	Jomar SD-4	32	92	Yes, it flies well, quite aerobatic
450hp Stearman "Black Baron"	1/6	64.5	1200	9	Astro 90 sport 16x8 APC	24	SCR 1 .2Ahr	Jomar SC-4	17	64	Bill Barber’s airshow Stearman - I fly his solo routine in memory
Percival Mew Gull	1/4	74.5	800	10.25	Astro 60 sport 13x10	28	SCR 1.2Ahr	Jomar Maxvell	30	68	1938 winner of British King’s Cup race
ZIin 526 AFS	1/6	65	650	6½	Astro 40g 12x9	20	SCR 1.4 Ahr	Jomar SM-4	23	77	Designed for FAI turnaround
Horten IX V26	1/10.5	62	750	6	Twin-Astro 05 modified	20	SCR 1 Ahr	Jomar SM-4	18	110	Twin ducted fan: homemade 2 5/8-inch rotors turn 32,000rpm 120mph
King Crimaon	?	126	2000	10 1/4	Four Leisure 05 ferrite geared 10x8 Rev up	28	SC 1.2 Ahr	Jomar SC-6	12	55	Spring Air Retracts design based on Horten bros. flying wings
Aerocommander Shrike	1/10	42	200	36 oz.	Twin Astro 02 5.5x4.5 Master Airscrew	8	SCR 0.9 Ahr	on/off singte/twin	20	50	Bob Hoover’s airshow twin does twin-motor, single-motor, dead-stick routine
Measerachmidt M35b	1/6	65	630	6	Astro 25g 12x10	14	SCR 1.8Ahr	Jomar SM-4			Willi Stor’s German aerobatic champion 1936