A Radio-Control Primer

Has DXing got you down? Ragchewing lost its luster? Morse code suddenly too cryptic? Radio-Controlled flying, boating or driving is an exhilarating way to enjoy Amateur Radio. These hams love it—and you will, too!

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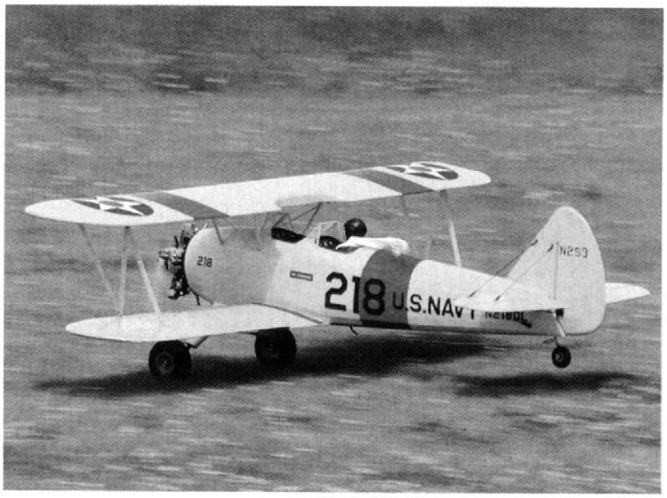
Radio control (RC) of remote objects is a significant extension of the mystique of radio communications. In place of exchanging messages "via the ether," direction is given to a remote object. In the recent Gulf War this capability was positively demonstrated through the use of Remotely Piloted Vehicles (RPVs). These radio-controlled model-size aircraft saved lives and helped expedite the war.[1]

Controlling RC models introduces an element of adrenalin-stimulating excitement that isn't often found in mainstream Amateur Radio—working a rare DX station may come close but, in any case, much less frequently.

The thrill of racing cars, boats, or aircraft can be compared to any sport, as a competitor or spectator. The joy of making your first good landing has to be experienced to be appreciated.

RC is a diversified hobby. Your author is considered an expert in the design and construction of RC seaplanes, a growing specialty of RC airplane activities. The technical aspects of good model design, engines/motors and electronics are challenges that many prefer to actually controlling the models. On the other hand, many fliers who compete in precision aerobatic events spend hours every day practicing. A vice president of a major American corporation practiced for many years from 4 AM to 8 AM while his wife stood by and offered encouragement. In retirement, he is still competing nationally.

[1]Notes appear on page 18.



Don Forte's big PT-17 scale model is on its take-off roll. The model spans 78 inches and has a five-cylinder rotary engine. (The original PT-17s had nine-cylinder engines.) This World War II trainer model can perform stunts that the full-scale original cannot. It's shown here in US Navy colors.

There are many small RC models. Most are not for beginners. They tend to fly very fast. The Livewire II, however, a redesign by the author of an early escapement-controlled model, is an exception. This model, with a 0.1-cubic-inch engine, will take off from a grass field and can be handled by beginning pilots with ease. *(photos by Ed McCarty except as noted)*

A large number of enthusiasts are controlling model cars, boats and aircraft by RC. In fact, there are more than 150,000 model airplane hobbyists in this country alone, and most of them fly RC airplanes.

Control systems are of two basic types: on-off and proportional. On-off systems typically go full right or left upon command. To affect a gentle turn, the control is applied intermittently (pulsed) and the aircraft's inertia smooths out the flight path giving the appearance of a continuous turn. Proportional control allows positioning a control (rudder angle, engine speed, etc) at any position called for by control levers or knob settings. All current RC systems are of the proportional type. (See the sidebar "Basic RC Systems" for more technical information.)

What Can Be Controlled?

Initially, RC was used to control model aircraft. In fact, the science predates the hobby. Elements were used by the military in World War I and in the 1920s. Model aircraft control has progressed from steering a model around the sky and hoping to land it in one piece to precision aerobatics, pylon racing, aerial combat (using streamers trailing behind the models) and many other types of fly-for-fun and competitive activities. (See the sidebar "The History of Radio Control" for more historical information.)

Many RC models are large; some have wing spans in excess of 10 feet. The photo shows Don Dixon, W1LIN, and his quarter-scale Pitts Special biplane. The Pitts model, like the full-size Pitts, is highly aerobatic. Its 2.5-hp engine has a chain saw ancestry. Unlike many amateurs who fly RC, Don is well rounded and involved in many phases of Amateur Radio. He got his license to fly RC on 6 meters, however, and then went into other amateur activities.

It surprises many people to learn that model aircraft can perform aerobatics that full-size aircraft cannot. This is primarily because they are not limited by the frailties of a human pilot. Although helicopters, because of their inherent lack of stability, are most difficult to fly, they also perform better than their full-size equivalents. Loops, inverted flight a foot-or-two off the ground and many other far-out stunts are possible. RC models are often used in movies to reduce cost and danger. The photo is of Brian Kickham and his helicopter at one of Cape Cod's model airports.

Model aircraft flying is a challenging sport. It is *fully* mastered by only a few talented individuals, some of whom are quite young. Helicopters are the most difficult models to fly. They are inherently unstable (like full-size choppers) and require continuous concentration by the pilot.

The thing that makes RC flying difficult is the fact that you must mentally put yourself into the cockpit of the model. Typically, right and left are reversed when the model airplane is flying toward you. Strangely enough, experience piloting full-size aircraft is of little or no value except for knowing the rudiments of what the various controls do to make the airplane perform in the air.

Most adults take six or eight months of practice flying once or twice a week to become comfortable with the control box. Unless absolutely necessary, don't try to teach yourself to fly RC models. An instructor will speed the learning process and save your trainer airplane from almost certain destruction. Most self-taught RC pilots never make it to the wonderful world of RC flying.

Don't be put off, though. Even if you never become a world-

The History of Radio Control

RC electronic equipment has been fully commercialized. The building of RC transmitters, receivers and servos has almost completely disappeared. As with Amateur Radio, in the early days of RC (1935 to 1950), much of the equipment was "home built" or built from kits. RC started with crude "escapement" type controllers that provided full right or left and sometimes up-elevator and/or high and low engine speed. These controls were effected by push-button switches. Hence, the term "busy thumb control" was born.

Next came a system that used vibrating control surfaces that produced a crude form of continuously variable (proportional) control. These systems were often called "galloping ghost controls" because the airplanes tended to waggle their tails and sort of galloped as they flew.

Another form of nonproportional control followed. This was "reed control," in which a bank of resonant reeds in the receiver sorted out tones sent by the transmitter. Switches on both sides of the transmitter kept both thumbs of a reed control flier busy. Many reed systems controlled more than four control actions (channels). A double-throw switch was required for each channel.

As elementary as they may seem, these systems allowed some amazing displays of aerobatics. The reed systems introduced the so-called "servo" actuator that operated the control surfaces and other control actions. Servos were the devices needed to make the transition to true proportional control.

The first proportional control systems used analog circuitry in which, typically, the transmitted signal consisted of a group of varying tones that were converted to voltages in the receiver. Analog servo actuators were controlled by these voltages. These systems were complex, heavy, expensive and subject to control drift. They didn't last long.

"Digital proportional" systems soon appeared and are still the standard. In these systems, a series of pulses is continuously transmitted—one pulse in the series for each control action. The receiver sorts the pulses into channels (control actions) and the servos react to the (averaged) pulse width fed to them.

The latest variation in RC control systems claims increased resistance to interfering signals—even on-frequency interference from other controllers. This is pulse code modulation (PCM), which requires a computer in the transmitter and receiver to encode and decode the control signals. "Fail safe" features are frequently included in PCM systems to preclude fly-aways and violent performance in case of abnormal or lost signals.

Guidelines and Other Things

• Don't try to reinvent the technology developed over the last 50 years. Readily available equipment is inexpensive, reliable, small, lightweight and well developed.

• Avoid grandiose first projects. Easy first steps will help you develop a lasting interest.

• The AMA has set up strict bandwidth standards for RC transmitters and receivers. These standards went into effect January 1, 1991, and are often called "The 1991 Rules." When followed, these rules allow simultaneous use of all 50 RC channels in the 72-MHz band, 30 channels in the 75-MHz band and 10 channels in the 50-MHz band (with the possible exception of interference from strong adjacent-channel commercial stations in the 72- and 75-MHz bands).

• License-free frequencies are in the 27, 72 and 75-MHz bands. Note that the original frequencies assigned by the FCC many years ago in the 72- and 75-MHz bands are now illegal.

• License-free frequencies for aircraft only are in the 72-MHz band. Similarly, surface vehicle frequencies are in the 75-MHz band. 27-MHz RC channels may be used for either air or surface vehicles. Amateurs may use the 10 channels assigned in the ARRL 6-meter band plan (50.8 to 50.98 MHz) and a series of eight frequencies (53.1 to 53.8 MHz) at the high end of the band. The 50.8-MHz frequencies are for airplane use and are covered by AMA bandwidth rules. The 53-MHz frequencies are broadly spaced and are not critical with respect to bandwidth except that they are close to repeater frequencies assigned in the ARRL band plan. With care, the 53-MHz frequencies can be used by both surface and air vehicles.

If you are operating a boat or car on these frequencies, make sure there is no one flying a model airplane on your frequency anywhere close at hand. Range for good control is more than five miles with ½-W transmitters and standard RC receivers. Aircraft are more vulnerable to interference because of the line-of-sight paths to them.

• Don't buy older RC equipment. It may be possible to reduce the bandwidth of an older transmitter, but it's a start-from-scratch case for older receivers.

• Avoid single-conversion receivers if at all possible; they are susceptible to image responses from other transmitters.

• RC systems are available with two to eight control channels. Powered aircraft need a minimum of three channels for effective control, but it's unwise to procure a system with less than four channels; someday soon you will want four or more channels of control. Cars and boats that require only speed and directional control (and simple gliders that use only rudder and elevator control) can be two-channel types.

• A four-or-more channel system can be "single" or "dual stick." This describes the transmitter's basic control configuration. Additional levers and switches can be provided for functions such as wing flaps, landing gear and so on. My preference is for dual-stick controls, each with dual functions: engine speed and rudder on the left stick and ailerons and elevator on the right stick. This is "Mode II" control in RC terms.

If the model does not have ailerons, the rudder is on the right stick with the elevator and the engine is by itself on the left stick. The aileron, rudder and elevator sticks are spring-return-to-center. The engine speed stick may be set and left in any desired position. Stick action can be modified to eliminate or add the centering feature. Single-stick systems normally provide aileron and elevator control with stick motion and rudder control via a knob on the top of the stick.

Some Technical Details

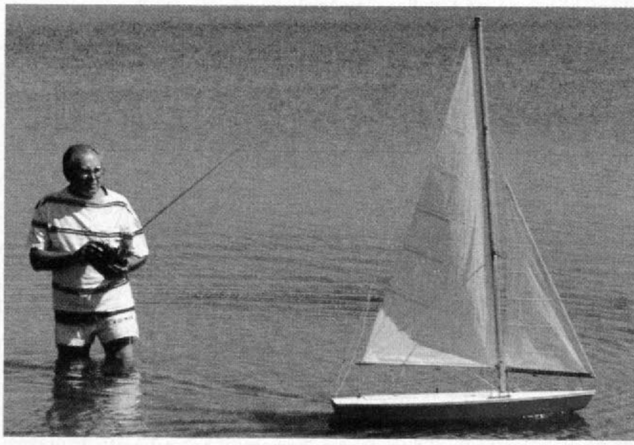
• Most current RC systems use transmitters, receivers and servos that are interchangeable (as long as they are both AM or FM and on the same frequency). Systems using PCM (usually FM) may not talk to each other if they are not from the same manufacturer. PCM systems use the same servos as other RC systems, however.

• RC systems of current design use pulse-width control to operate their servos. The mid-position pulse width is almost always 150 milliseconds (ms). The nominal min/max range is 100/200 ms.

• Signals for the various control channels (rudder, elevator, etc) are sent sequentially. A clock pulse resets the receiver's decoder and the string of pulses is sorted and sent to the appropriate servos. The control data is updated (repeated) at a rate of about 60 Hz.

• Modern servos use bridge circuitry to feed their drive motors. Three wires are required to connect them: two for the 4.8-V supply and one referenced to the supply negative for the control signal. (Older systems used a split supply voltage [4.8/2.4/0 V] and required four wires to connect them. These servos can be used with newer systems by splitting the supply voltage or, preferably, installing a new servo amplifier—kits are available). The newer servos apply the full supply voltage to the drive motors and are faster and more powerful.

Shown here is Bruce Selig, K1RRF, with his highly aerobatic biplane. Bruce has been licensed many years and uses his license only for RC. He is a super model builder and pilot. His modern RC transmitter (in hand) has many advanced features.



The quiet grace of a sailboat is always pleasing to the eye. In the photo, Hans Sagemuehl's boat performs on a Cape Cod lake. It has rudder and sail control and can do as well as its full-scale counterpart—but, at much less cost. There are many RC sailboat and powerboat clubs that have competitive and sail-for-fun sessions at lakes around the country. (Salt water is a hazard to the electronics and engines/motors in RC seaplanes and boats. Almost all RC boating and flying is done from fresh water.)

Basic RC Systems

Most RC systems consist of the elements shown in Fig 1. The hand-held transmitter has control levers ("sticks") and switches, and has a collapsible whip antenna. The airborne elements are a receiver with a wire antenna; a switch "harness" consisting of the necessary plugs, cables and an on-off switch; and as many servos as needed for the control surfaces and other features that are to be controlled.

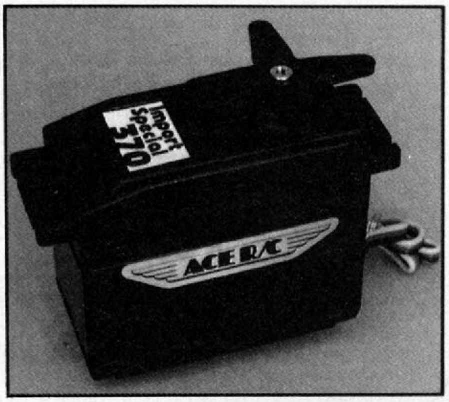
The positions of the levers and switches are encoded and transmitted by the hand-held transmitter. Power output is about ½ W, AM or FM, and is more than sufficient to control a model as far away as you can safely fly it. The coding is a repetitive string of pulses. The length of an individual pulse (ie, the 1st, 2nd, etc) determines the position of a given control.

The receiver sorts the pulses and feeds them to the appropriate servo. The servos compare the pulse lengths to a standard (usually 150 milliseconds) and react by positioning their mechanical output arms accordingly. These devices are true servomechanisms that draw very little current unless they are changing their output position. Thus, a servo converts an electrical input signal to a mechanical output position.

Several systems exist for coupling the servo output to the control surfaces or other controlled devices. Pushrods of metal, wood or plastic are most frequently used. Concentric plastic tubes; an outer, fixed conductor and an inner, movable rod are popular, especially when the path between the servo and the controlled device is not straight. Control cables are used in many scale models of older airplanes.

The transmitter and airborne batteries are powered by rechargeable cells. With proper care they will last for years in an average RC system. The airborne battery should be mounted in plastic foam to isolate it from engine vibration.

Control systems for cars and boats are similar. The exception is the servos used to control the sails on a sailboat. In this case, "sail winch" servos are used. These pay out or pull in the lines that go to the booms at the bottom of the sails.



This Ace R/C model 370 servo is the "giant" in the company's lineup. The splined shaft (top right) rotates up to 90° (the four-pronged output arm mounted on the shaft allows for mounting and installation flexibility). The tabs on the "skinny sides" are for mounting the device. *(photo courtesy of Ace R/C, Inc)*

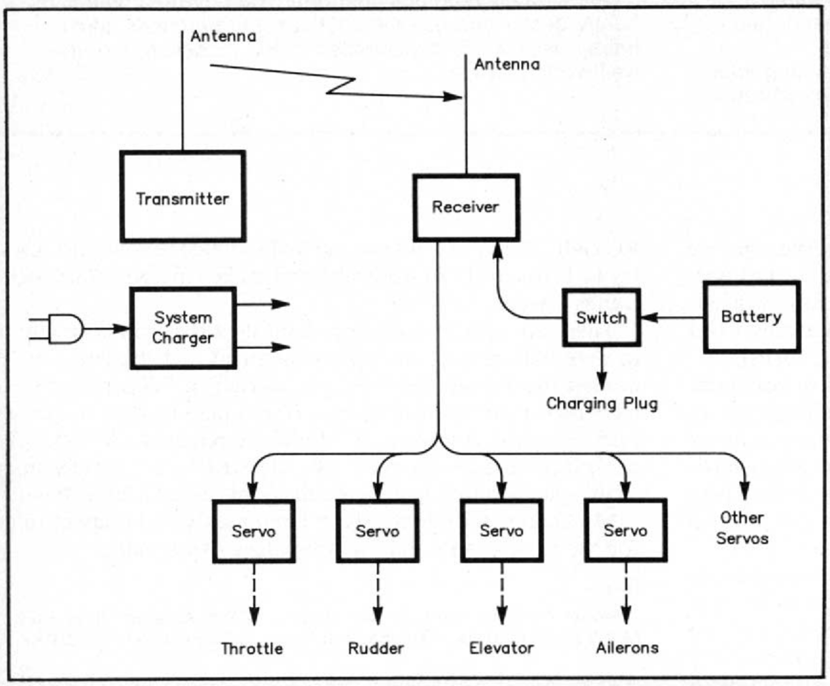
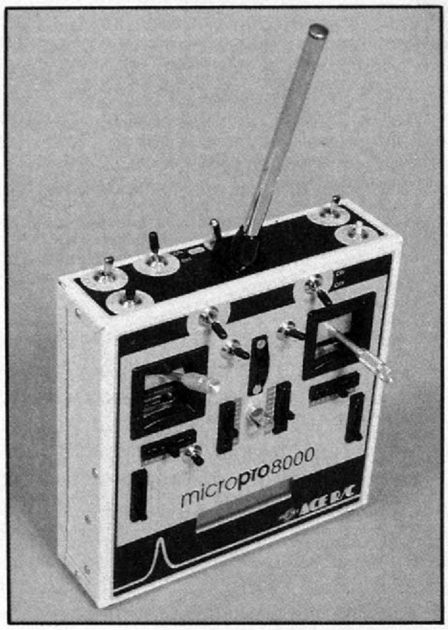


Fig 1—Shown here is a block diagram of a basic RC system. Additional channels/servos can control features such as flaps, retractable landing gear, a camera, smoke generators and lights.



The Ace R/C Micropro8000 radio-control transmitter is typical of today's advanced dual-stick RC controllers. The '8000 is microprocessor-driven (when new features are introduced, simply replace the unit's ROM chip), has eight channels, an LCD readout, automatic trim functions and many advanced features. *(photo courtesy of Ace R/C, Inc)*

class RC pilot, you can still have a lot of fun flying your less-than-glamorous trainer plane and performing less-than-glamorous everyday maneuvers!

Surface models are an alternative to model aircraft and, while they do not require the controlling skill of their airborne cousins, they do require great skill in competition. Cars, power boats and sailboats are all popular. Many scale boat models are worthy counterparts of scale model aircraft. The attention to detail in scale modeling is a dimension in itself. Scale sailboats look and sail just as their full scale equivalents do.

Bells and Whistles

Today's RC equipment contains many special features that make the hobby more enjoyable. Transmitters feature such things as flight timers and digital battery-voltage displays. Servo reversing switches allow you to use several airplanes with one trans-

Getting Started

The following are popular model choices for beginners. Kits for building them are available from hobby shops. All of these kits come with detailed instructions to help first-time kit builders.

Aero-Star 40 (or 20), from Midwest Products Co, Inc. This kit has a very good set of instructions.

Headmaster Sport 40, from Top Flight Models, Inc.

Kadet MK II, from Sig Manufacturing Co, Inc. This model is a great trainer, but takes some patience to build. It is one of a family of Kadets both larger and smaller.

PT-40 (or 20), from Great Planes Model Manufacturing Co. This is a very easily built trainer.

Telemaster 40, distributed by Hobby Lobby International and manufactured by Great Planes Model Manufacturing Co. It is one of a family of Telemasters, both larger and smaller.

Note that all of the above models have "tricycle" landing gears. They have nose wheels rather than tail wheels. Tricycle gears save propellers during steep student landings and make steering on the ground easier.

In addition to *Model Aviation* (you get a subscription when you join the AMA), the following magazines are sold by subscription, by hobby shops and at news stands: *Flying Models, Model Airplane News, Model Builder, Radio Control Modeler* and *R/C Report*. All of these magazines are largely devoted to RC models. There are also several specialty magazines covering scale models, cars, and boats. Magazines keep you updated on equipment, model-building techniques and rules changes.

In addition to a model kit, you will need an engine, a propeller, wheels, a fuel tank, some minor hardware, covering material, a radio system, a starting battery and glo-plug connector, a fuel pump and an electric starter/battery or a "chicken stick" for hand cranking your engine. The latter device protects your fingers as you turn the propeller. Most engines start quite readily when "hand propped."

To build the kit you will also need modeling pins, adhesives and other readily available items. For general construction purposes, an aliphatic resin type glue like Tite-Bond is recommended.

A two-cycle glo-plug engine is recommended for your first model. The Fox 40BBRC Standard (Fox Mfg Co) and K&B R/C Sport 20 (K&B Mfg Co) are good first engines. The "40" and "20" stand for 0.4- and 0.2-cubic-inch displacements.

The K&B 20 is famous for its quiet operation. Use the propeller recommended by the engine manufacturer. Use great care when operating model airplane engines; 40- and 20-size engines deliver about ½ horsepower.

Get help from an experienced modeler if you can. There will be many questions that will arise. In any case, build your model carefully in accord with the plans and instructions. The flying surfaces must be warp free. Wing, tail and engine-mounting angles are all critical. If at all possible, have an experienced flier test fly your model.

Several of the large model supply companies publish excellent catalogs that feature helpful information for beginners. These catalogs cost $2 to $3 and are well worth their cost. See your hobby dealer or write to: Ace R/C Inc, PO Box 511, Higginsville, MO 64037 ($3); Sig Mfg Co Inc, 401 South Front St, Montezuma, IA 50171 ($3); Indy R/C Sales Inc, 10620 N. College Ave, Indianapolis, IN 46280 ($2); Hobby Lobby International Inc, 5614 Franklin Pike Circle, Brentwood, TN 37027 ($2).

It is strongly recommended that you buy from your local hobby dealer and use the catalogs as references. Most hobby dealers are experienced in RC modeling and are well worth knowing.

mitter (without having to build each airplane so its servos operate in the same direction as the others when commanded by the transmitter). Coupled controls are offered in some systems. Typically, this makes an airplane's rudder operate automatically when you call for aileron control (it helps to coordinate turns).

The most sophisticated control transmitters have computer memories that allow you to program the initial settings for up to eight airplanes. Among other things, the transmitter remembers proper servo directions, control surface trims, planned maximum flight times, engine cut-off control settings and so on. These bells and whistles cost money—but they're worth the price to many of us.

Up-to-date five-channel RC systems with servo reversing capability, four servos and the necessary switch harness to connect the airborne components and NiCd battery packs can be purchased for less than $275. Other systems that perform very reliably sell for as little as $150 at discount prices. All told, with an airplane, an engine, starting batteries, fuel and so on, you can count on spending about $400 for your first system. Second-hand bargains can save you money, but make sure you know the seller and get a guarantee. As with Amateur Radio equipment, RC equipment holds its resale value.

Conclusion

As Amateur Radio operators we can enjoy the special privilege of operating RC models on relatively uncrowded 6-meter frequencies. Most RC hobbyists use license-free frequencies in the 27, 72 and 75-MHz bands. Because of the number of hobbyists and interlaced commercial users on these bands, they often become crowded at many popular RC sites.

The best approach to RC is through your hobby shop and local RC club. The shop will steer you to the club(s) in your area. Don't try to learn to fly by yourself, and make sure you start with a trainer model.

There are several magazines published that will keep you up to date with respect to rules, equipment and the latest in RC models (see the sidebar "Getting Started"). RC cars and boats have dedicated magazines, too. If you plan to fly a model aircraft, join the Academy of Model Aeronautics (AMA).[2] This organization is set up much like the ARRL. It provides many of the same services, including a magazine called *Model Aviation*.

My thanks to Ed McCarty, a longtime flying buddy of mine, for the photography that accompanies this article.

Notes

[1] "Model Airplanes Go to Desert Storm," *Model Aviation*, June 1991.
[2] AMA Headquarters, 1810 Samuel Morse Drive, Reston, VA 22090.

Strays

WEST CHICAGO BBS

☐ The Suburban Commodore Users' Group (SCUG) BBS features ham radio/communications, law-enforcement and general-interest messages bases; file transfer areas for Commodore, IBM, Tandy, Amiga and Apple Macintosh computers; online games; graphics; electronic mail and more. It's operated by Will Sperling WA9YHX, and his son Gregg, KB9DBC, of Westmont, Illinois. The BBS is available 24 hours a day at 708-852-1292 (300/1200/2400-8-N-1).