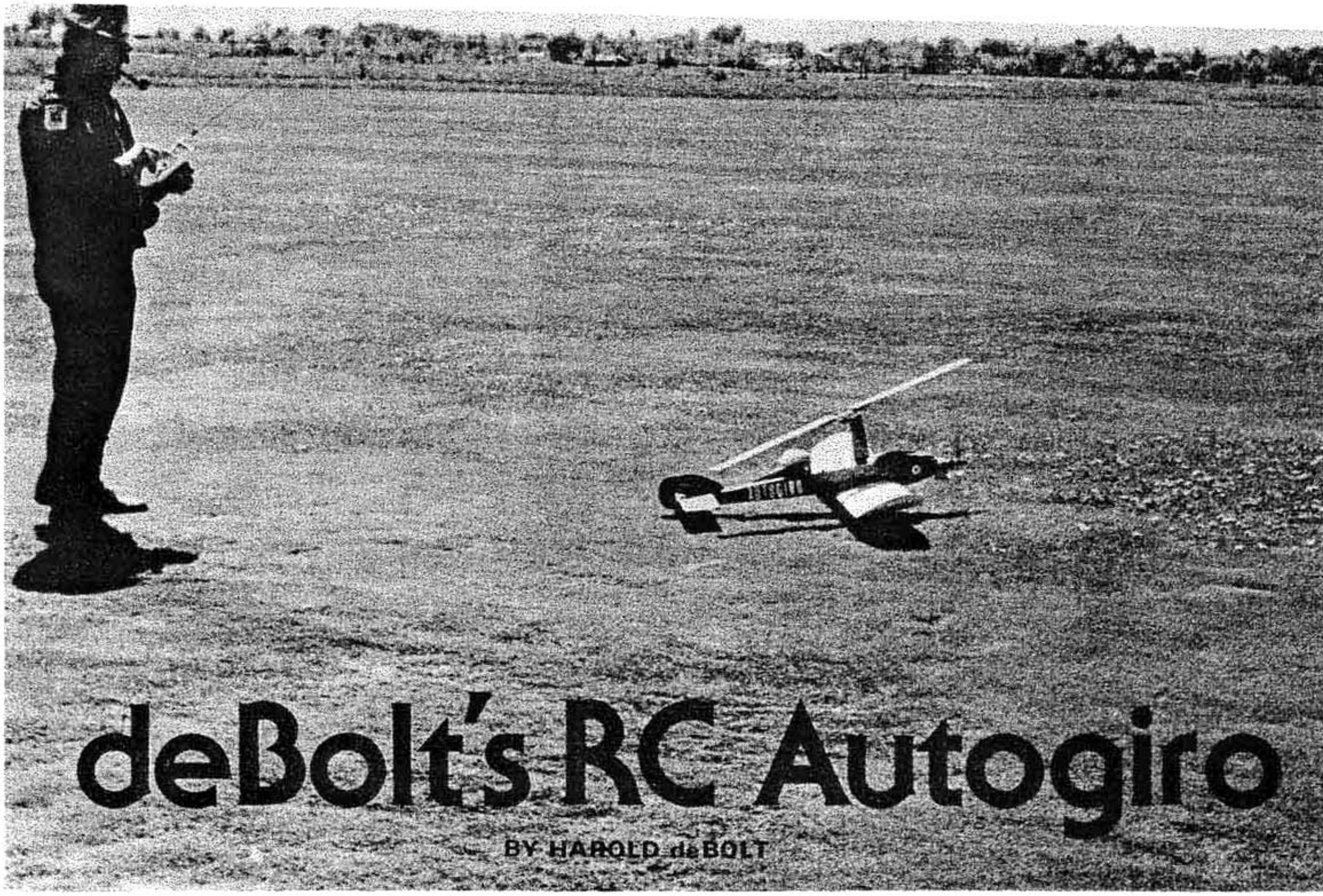

deBolt's RC Autogiro

BY HAROLD deBOLT

Ready for lift-off. Flick of the finger started rotor rotation to begin the short takeoff roll. Only 50 rpm of rotor sufficient to get it off!

Famous "old-timer" took time out to explore the mysteries of rotating wings and used one of his original designs to develop this fine flying Autogiro.

• From the number of "What is it?" questions I have heard since I have been developing this model, the age of the *Autogiro* design concept is quite apparent. The *Autogiro* dates back to the early 30s and it is one of the few "funny type" airplanes of that period which became successful. Today we find them only in museums, and very few of them at that, because the helicopter does the *Autogiro's* work better in most cases and we are affluent enough to afford the 'copters.

The *Autogiro* was invented by Juan Civera of Spain and further developed by the Kellett and Pitcairn corporations of the U.S.A. The airplanes of that day were rather underpowered in most cases and the engines not all that reliable, plus "blind flying" was yet to come. The combination of unreliable engines and tricky weather made aircraft safety something to be desired. Obviously if you had an engine failure or the weather was closing in, your object would be to get on the ground as quickly as possible. This was not always possible without crashing because of the scarcity of flying fields. As a result the major objective for designers of that period was the achieving of greater safety in flight.

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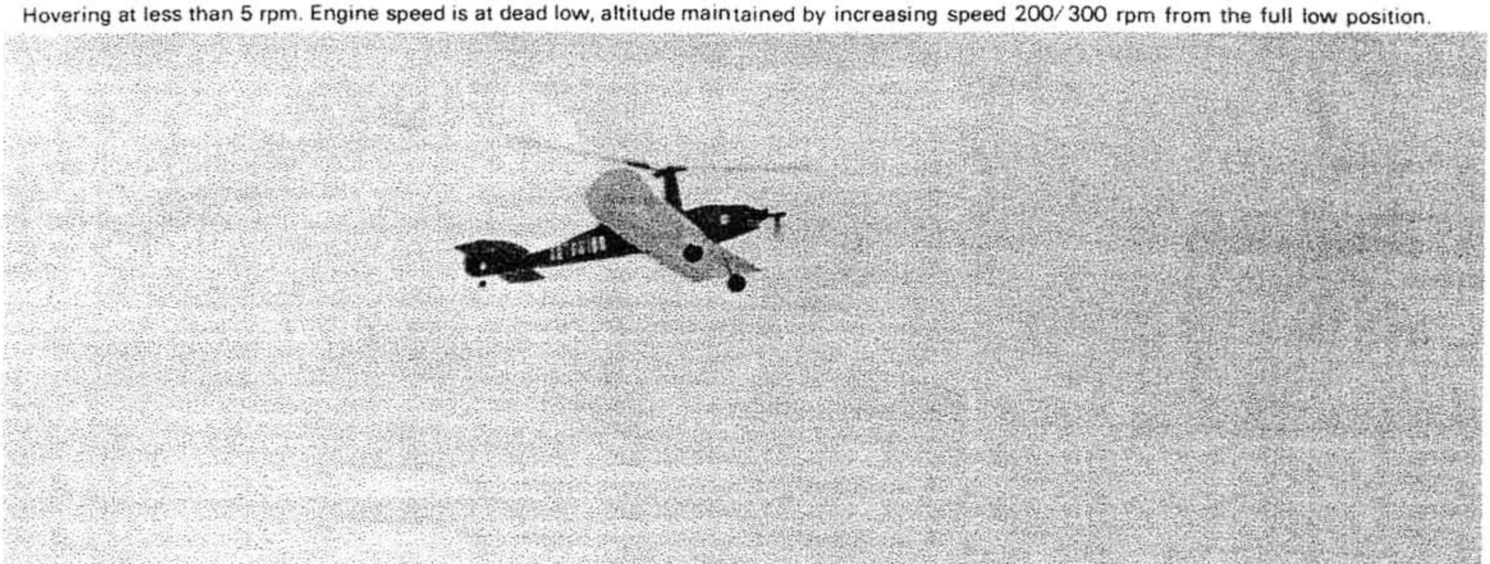
Hovering at less than 5 rpm. Engine speed is at dead low, altitude maintained by increasing speed 200/300 rpm from the full low position.

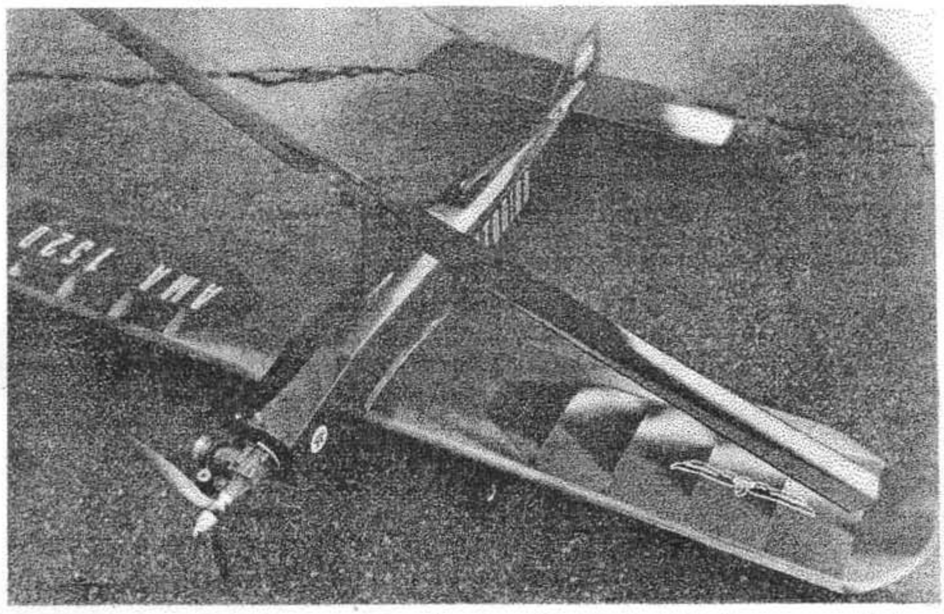


de BOLT'S R/C AUTOGIRO CONTINUED

Civera's design parameters for obtaining safety forgot about improving the engines and blind flying technique. Instead, he set about designing an airplane which could land and take off from the smallest of fields, one which did not require an airport from which to operate. Additional requirements were the ability to descend steeply and quickly with a dead engine. After considerable effort and much frustration, Civera accomplished his purpose very effectively. He gave the world a much safer airplane and one which did aviation a lot of good during the time it took to develop reliable engines and to learn about blind flying.

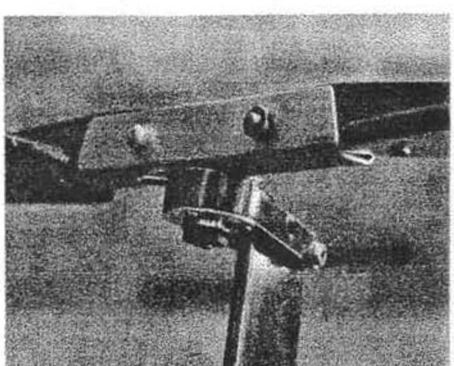
Being an old-timer I have long had the desire to have an R/C Autogiro, not from the nostalgia, but because I knew enough about them to know that they could easily add a WHOLE NEW DIMENSION to our R/C flying. Consider these factors if you will: An Autogiro flies and controls exactly the same as an airplane; any R/C airplane pilot can fly one without special training. In the air it duplicates the flight of an airplane, so we have an airplane with some very different and desirable flying characteristics. A 'Giro will take off in less than ¼ the distance required for an airplane. It will ascend vertically on takeoff if desired. In flight it will attain normal aircraft flying speeds and is very maneuverable. When desired it will also fly at near-zero forward speed. With a dead engine it will descend very steeply and slowly. Landings can be made a la airplane but with practically no roll-out by comparision, or the landing approach can be set up for a nearly vertical descent with no roll-out. Hovering flight is obviously one of its assets: it will easily stay in one spot in the air for as long as desired. An Autogiro does require a bit of forward motion or an airflow of another sort to maintain flight. Thus it is obvious that any breeze is an asset to its flight; the whole performance becomes ultimate when some wind is present. When you add this performance to our normal sport flying, it becomes obvious that you have an entirely new way of flying that is not only advantageous but also considerable fun too!

Final version includes a repositioned rotor, shock-absorbing L.G., engine down thrust.



Lift created by rotor far greater than the size of rotor would indicate, very efficient.

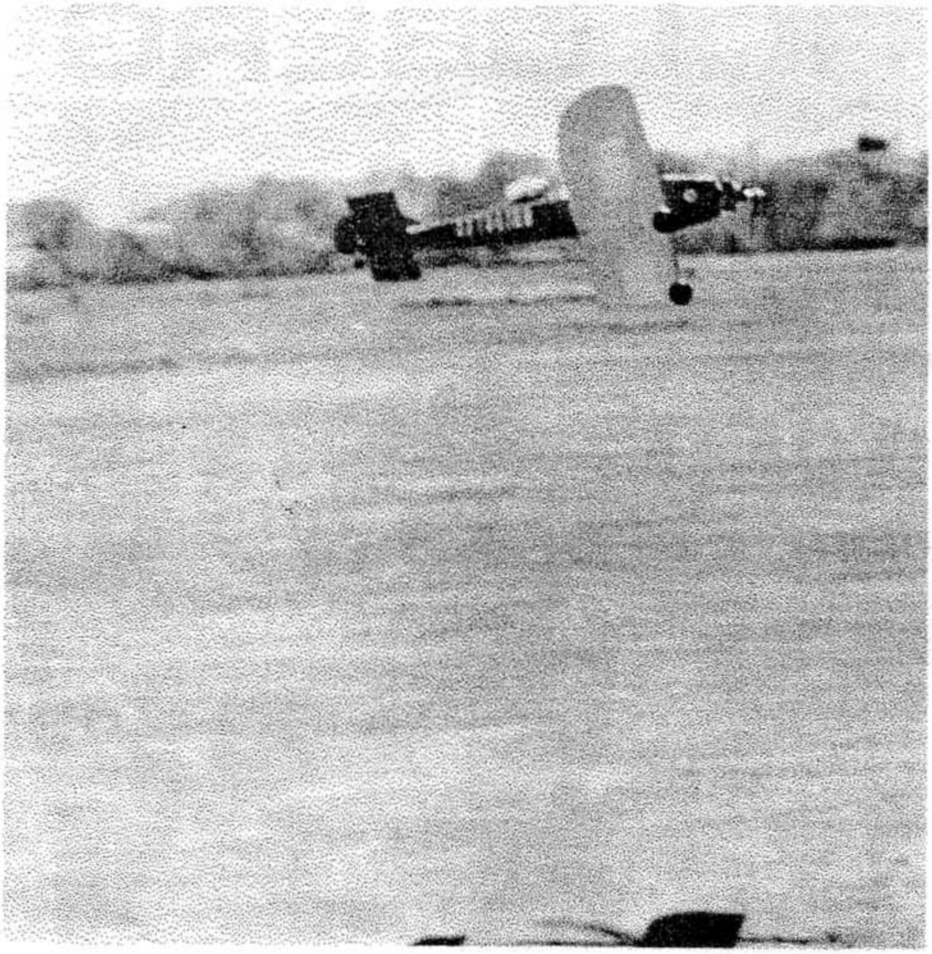
Autogiro inventor Juan Civera suffered many failures before solving the mysteries of the Autogiro; without engineering data, the model Autogiro encountered similar problems.



Rotor head design proved practical from the start, simplified by use of flanged bearing.

Over a year ago I decided to do something about my desire for a 'Giro and thus commenced a very long and tedious period of development. When I got into it, I found that due to the passage of time there was very little information on Autogiros readily available. Descriptions could be found but engineering data was practically nil. Thinking that I was a pretty fair aerodynamist I approached the problem using that knowledge and soon found that what I knew was probably excellent for airplanes, but an Autogiro was a entirely different kettle of fish. However, in spite of many problems and crashes which resulted, the search for the answer proved very instructive and the engineering concept turned out to be quite sound and fundamental, once it was understood! Needless to say, the design presented here is the result of these findings, and I have enjoyed hundreds of successful flights with it. With this accomplished, I feel that my original desires have been fulfilled, and no further development could be made of this particular design concept.

The basic concept of an Autogiro is the *(Continued on page 38)*



Maneuverability shown in this 360 degree turn started here. Engine at 25% of full throttle.

de BOLT'S R/C AUTOGIRO . . . CONTINUED

powering of a lifting rotor by an airflow, instead of with an engine, as in the case of a helicopter. The rotor is caused to turn in much the same manner as a windmill, the difference being that the 'Giro's rotor is set up to develop lift, rather than just to transmit power as the windmill does. The 'Giro's rotor revolves as a result of any air moving past it, forward speed of the airplane, descent of the aircraft caused by gravity, any breeze present, or a combination of any of these forces. For a windmill or rotor to absorb an airflow, the blades must be set at a negative angle to the direction of rotation. This is where Civera used a bit of "cute" aerodynamics which made the *Autogiro* successful. There are some good lifting airfoils which still develop lift down to as low as a 5 degree negative angle of incidence. It only requires about 1 degree negative to cause a rotor to rotate, so with such an airfoil a rotor will turn successfully and develop usable lift. Of even greater use to the *Autogiro* when a rotor is rotating, aerodynamically the lift comes from the disc created by it instead of just from the blades themselves. This is similar to the lift created by a propeller's disc which is much greater than that which could be obtained from the prop blades alone.

The basic idea has proven excellent as the success of the *Autogiro* demonstrates; however Civera got into considerable trouble when he tried to apply it to an airplane. He did not investigate the idea thoroughly enough to realize that the lift generated and other forces created varied considerably throughout the rotation of the rotor. He assumed the center of forces to be at the axis of the rotor when they are actually forward and to one side of it. As a result every time he attempted to fly he would stall and roll to one side when takeoff speed was attained. After many trials and errors the answer proved to be articulation of the blades and the use of another "cute" aerodynamic trick. An *Autogiro* has been called a "flapping wing" machine: the description comes from the hinged blades which rise and fall (or articulate) throughout their rotation. This articulation evens out the forces generated due to the changing dihedral, which tends to equalize the lift as the blades rotate. The result is a lifting disc which is both usable and stable.

The first successful Autogiros used a small wing as well as the rotor. The last developments of the 'Giro did away with the wing. A wingless Autogiro approaches the complexity of a helicopter and thus the simplicity disappears. The wing of an Autogiro serves more as support for the ailerons than it does as a lifting device. With the simple rotor something is needed for lateral control and the ailerons provide this very well, just as with an airplane.

I chose the winged version for the rotor (simplicity, of course), but it does have an added advantage that is most usable for us R/Cers. The R/C Autogiro can be flown and TRIMMED OUT as an airplane before the rotor is installed. When test-flying, this allows many questions to be resolved before rotor flight is attempted. Another misconception about Autogiro design concerns the reason for the down thrust used. Usually it is thought that setting the propeller at such an angle causes a better airflow through the rotor. However, the actual reason is much more practical than that. Actually down thrust has very little effect as far as air flow is concerned when an airplane has reached flying speed; it does have a strong effect when the aircraft is stationary or nearly so. An Autogiro has two flight speeds which are normally used, very slow and fast. When a 'Giro is hovering, the rotor is developing a major portion of its lift, the wing practically nothing. When any forward speed is added, the wing immediately starts to lift also. Then too, right at this moment of transition from slow to faster speed, down thrust has its greatest effect, tending to pull the nose down. This down thrust effect adds stability when the major lift is from the rotor alone and, secondly, it helps to balance out the additional lift from the wing as acceleration occurs. As soon as forward speed has been attained the other stabilizing factors take effect, such as the stabilizer, and the craft flies as an airplane once again. The most important thing down thrust does is provide a smooth transition from low speed to high speed flight.

Suffice it to say that with no more information available to me than Civera had to start with, I saw the same pitfalls that he had, develop as I worked with the design. Fortunately for me I was working with models instead of the many full-scale machines which Civera destroyed in his search for the answers. But, like him, I learned too and the end result was well worth it.

It is anticipated that if you have the desire and ability to construct a model such as the Autogiro, you will not need step-by-step instructions to assemble such a simple airplane design. Simplicity was used to offset the time needed to assemble the rotor so that the end result is no more time-consuming than the average sport model of today would be.

Of immediate interest of course is the rotor assembly and what is needed to make one. Fortunately the entire assembly is produced from "off the shelf" items which are easily available in your hobby shop or a good hardware store. No precision machining is required but some good workmanship is needed: the rotor assembly can not be thrown together sloppily and have it work right. If the proper procedures are followed the results will be excellent.

I managed to break up several sets of blades in finding out what the score was. This gave me the opportunity and incentive to try several different materials and

(Continued on page 96)

Autogiro

(Continued from page 38)

methods, also with airfoils. Fundamentally, the rotor assembly is a rotating mass. Anything that gets wound up like this does creates a lot of inertia and forces. To keep these to a minimum it is obvious that the lighter it is, the less forces result. Also, the rotor changes speed at various times during flight. In high-speed level flight, for instance, the rotor rpm is the lowest. At hovering speed it is highest. We wish to change from one mode of flight to another stably and quickly. Therefore rotor acceleration is important. All factors point to the lightest rotor's being the most efficient. Maximum rotor speed is only 500 rpm which is an asset. Extreme strength is not required, therefore various forms of balsa are quite sufficient for the blades. Fairly light balsa is easy to shape and when covered wtih ¾ oz fiberglass cloth and finished with polyester resin, it has more than the necessary strength. Perhaps simpler and just as efficent are blades made from medium-hard balsa and finished with the resin only, saving the application of cloth. Also it was good to find that a broken blade could be repaired simply and become usable again.

The type of airfoil also proved important. It is necessary of course to use a high lift airfoil which lifts well at a negative angle of attack. Important too is the choosing of one which has the least drag. Obviously, the faster the rotor turns, the more is the lift generated. Reducing drag gives a higher rpm automatically. The airfoil shown is a high-lift type with low drag and showed more promise than a higher drag type that was tried initially. Airfoil thickness also proved important, the successful one is ¼" thick, about 12 percent. A 15 percent airfoil was not stable and the rotor rpm was much lower.

The blade hangers were made from maple engine mount stock which can be had from the hobby shop. They were run through a table saw with the blade set at a 3 degree angle which provided the blade incidence easily. The center line of this airfoil is 2 degrees above its flat bottom on which the hanger is fastened. As a result when the blade is screwed to the hanger with its 3 degree angle, the true incidence of the airfoil becomes the 1 degree desired. Also, the flat bottom remains at the 3 degree angle which gives more "windmill" effect.

The rotor hanger is cut from a piece of standard aluminum channel which is carried by good hardware stores. It is simply cut to length and the necessary holes drilled in the prescribed locations. Accuracy of assembly is obtained by using the already drilled aluminum rotor hanger as a drill guide for the maple blade hangers. Simply insert the maple blade hangers into the channel in their proper locations and use the already drilled holes as a guide for the blade hanger axis holes. The hanger axles and bearings are cut from the prescribed tubing. The bearing should be a press fit in the blade hanger and the axle tube should be about .055" longer to allow free movement. The free movement is required so that the articulation will occur quickly and easily.

After the rotor support has been made the rotor can be hung on it and the blades' diameters equalized. They should also be balanced of course: small amounts of weight can be added at the tips to accomplish this. However, if both blades are made from similiar material and the airfoils are alike, very little balancing should be necessary. The rotor support is quite important as it is subject to some pretty heavy loads in flight. The heart of it is the flanged ball bearing, which obviously keeps friction to a minimum, helps with articulation (because of the small amount of play that is inherently in it), and also makes the support simple to fabricate.

The idea is to make a sandwich of the necessary thicknesses of plywood which will lock the bearing in place and serve as a means of attachment to the rotor pylon. The critical layer of the support is the "B" layer which holds the bearing. This layer requires a ⅝" hole which must be a press fit for the bearing, so try your boring tool in some scrap for hole size. These holes are all large and in a small piece of material, so it is best to drill them in the plywood before the parts are cut to shape. Note that layer "C" is counterbored slightly to allow clearance for the bearing flange. The pylon slot should be a tight fit on the pylon; after assembly on the pylon the support should be tack-glued in place. A drop of Hot Stuff does this neatly. In assembling the rotor be sure to check the balance of the blades, the blade incidence and the rotor angle of attack. All are important. The maximum articulation dihedral angle should not be greater than called for. The clearance between the blade and the fin is important for safe operation also.

I used "nature's wind tunnel" for all the experimental rotor testing and it comes in handy to check rotor operation at any time. Simply take the 'Giro outside in a breeze; when it is held up so that the nose is at about a 30 degree angle upwards, the wind should revolve the rotor easily. Caution! Once the rotor is revolving, do not try to stop it with your hand for obvious reasons; instead, simply lower the nose until the wind is striking the top of the blades and the rotation will stop. The rest of the model's construction is straight-forward. Some of the landings will be rough in windy weather due to turbulence and possible cross winds, therefore a bit more strength is needed in the forward fuselage and a rugged shock-absorbing landing gear is required, so make no changes in this construction. You will notice the dihedral in the wing—in fact it has polydihedral similar to a Free Flight wing. This is important for adequate directional control at very slow speeds. It also assists lateral control at such speeds. Dihedral complements rudder control and makes it more effective, and also helps to maintain the wing level in turbulence: dihedral does a lot of work for you that is helpful. The wing could be made from foam, of course, if you are inclined to that type of construction. The original wing used on the test model had the landing gear mounted in the wing in the conventional low wing manner. This type of mounting did not have enough shock absorption for the vertical Autogiro-style landings. Otherwise, there is nothing unusual about the construction and it can be accomplished in the usual way.

As was said before, the Autogiro responds to the controls in the same way as conventional airplanes do, so it is flown in exactly the same way EXCEPT WITH A BIT MORE CAUTION at hovering and landing speeds. At these real low speeds steering of the craft must switch from ailerons to the rudder as the air flow over the wing becomes practically nothing resulting in the loss of directional control by the ailerons. However, the ailerons will still serve as a means to keep the wing level. The advantage of THIS Autogiro is that initial test flights can be made without the rotor and it is smart to follow that procedure. Assuming that a normal complete preflight has been made and the control actions have been set up as you would for an airplane, test flights can proceed. The model should be quite quick in the air and landing speeds will approach that of a Formula 1 because you do not have much wing area. Obviously you should watch for the usual trim requirements and adjust so that with neutral controls flight is very flat at full throttle and of course that it flies straight hands-off. Other than that, keep a careful check on the low speed engine operation. The engine must idle as low as possible and be completely reliable especially when idling for long periods and during transition from low to high. The engine control becomes a primary control and is very important in the flight of an Autogiro. Assuming that you have the engine operating reliably and all flight trims made, the rotor can be attached and its rotation checked in your "wind tunnel." Before the first Autogiro flight all control movements should be INCREASED by about 50 percent, maintaining the same trim conditions as you had attained. You will need this additional movement at the extremely low flight speeds when the controls become sluggish due to the lack of airflow over them.

Perhaps it is best to make the first Autogiro flight in the same manner as you did flying it as an airplane. This should build confidence and give you a feel for the control reactions now that the rotor is operating. Let us proceed with such a flight and then follow with the "good" flying later.

Unlike an airplane Autogiro must take off DIRECTLY into the wind at all times and no matter how light the breeze is. The reason for this is that any cross wind will "unbalance" the lift of the rotor disc and cause a sharp bank at lift-off with the wind. Once airborne, the stability factors will take over and cross winds are no more of a problem than with an airplane. However, you can imagine that there can be some "hairy" moments at lift-off if the correct procedure is not followed.

With this in mind, with the engine a bit above lowest speed and the 'Giro headed directly into the wind, the rotor is given a sharp "flick" to start its rotation. With the elevator held at neutral and as quickly as possible after starting the rotor, the engine is advanced to about 2/3 throttle. The takeoff run should be similiar to an airplane and no elevator should be used to "horse it off." If all is correct the Autogiro will lift off in a relatively level position and a normal airplane-style climbout should be accomplished. Once airborne fly it as you did without the rotor and again check for any needed trim adjustments. Once trimmed, (if it was necessary), fly it around at full throttle and get a feel for its control reaction. It should not be "horsed around" in pylon-type turns, as in such turns there are abrupt changes in the airflow which can cause the blades to start "flapping" with all sorts of reactions until level flight is had once more. This is not to say that normal sharp turns cannot be made, just work into them gradually until YOU have a knowledge of the reaction. In fact, an Autogiro should always be flown "full scale" style, keeping the nose on the horizon and flying through all maneuvers instead of "horsing" it as we tend to do at times with our models.

Once you are satisfied that you have a good "feel" of the flight, a landing can be made. Set the first landing approach up in exactly the same manner as you would for an airplane and proceed in this normal manner until the touch down is attained. Just as with an airplane, as you approach the touch down time use the elevator to keep the nose a bit high, but do not overdo it as you will commence to hover. The landing then will not be normal and could require the use of engine control which you are not ready for as yet. This whole landing procedure should come off in exactly the same manner as it would if the Autogiro were a true airplane. More familiarization flights can be made of course and probably are a good idea. However, here we will proceed immediately into the "different" flying that can be done with a 'Giro. With this description we will assume that you have a full understanding of the flight as it has been done to this point.

The first attribute of an Autogiro is its ability to make very short run takeoffs and immediately assume a steep climb-out. To accomplish his, the 'Giro is headed directly into the wind and the rotor started as before. This time, once the rotor is revolving and with the elevator in neutral, advance the throttle FULLY. As the run begins, steer it if necessary of course, but also watch the rotor speed. When you are sure that the rotor speed is positive and steady, ease in the up elevator and keep watch of the model's angle of climb as it lifts off. The object of course is not to go beyond a vertical angle which the Giro is perfectly capable of doing. The point is that at lift-off speed the 'Giro has sufficient speed to become fully maneuverable, which is different from an airplane. With this procedure you should have lifted off in about ¼ the distance an airplane uses. You will notice that the angle of climb which you attained can be maintained to whatever height you desire. The rotor maintains its lift at all speeds, so you are using this lift in the climb and, unlike an airplane, as the forward speed drops in the climb you will not lose the lift required to maintain the angle.

Once in level flight slow speed and hovering flight may be attempted. To reduce from full speed to hovering requires about 200 ft. in distance so position the 'Giro accordingly. The transition is made similiarly to an airplane, simply throttle back and as the speed reduces keep the nose level with the elevator. As the speed approaches minimun, control applications will not have to be made as quickly as necessary at full speed; however you will have to use a greater number of controls. You will note that these additional controls have a distinct effect on the maneuverability. Remember that if you become disoriented simply applying more power will pull you out of the predicament and you can always try again. As you reach minimum speed you will notice that the ailerons will no longer change the 'Giro's direction, but they will, with full application, keep the wing level. As a consequence, at these low speeds all steering is done with the rudder. Over control with the rudder can cause the 'Giro to "dutch roll" or oscillate. Therefore an adjustment could be necessary to reduce the amount of rudder control available until the response is below the oscillation level; it still will be sufficient for steering.

Both engine and elevator controls are used during the hovering maneuver. The approach to hovering is made with minimum throttle by gradually applying up-elevator to keep the nose slightly above horizon level. As the hover position is reached the nose will probably be somewhat higher than it was on the approach. At this time the 'Giro will start to descend slowly but steeply. Altitude is maintained by a slight addition of power; do not overdo it or else the hover will be lost and you will have to start over. You can actually jockey the engine control at this point and easily stay in one position at a steady altitude. Things happen rather slowly so you have time to think and use whatever of the controls are obviously necessary. There is no reason to panic either, as this same approach procedure is used to perform a power-off landing. So the worst that can happen is an unwanted landing! It is reassuring to know that once in flight and barring a mechanical failure, the rotor will never stop or quit lifting, so unlike an airplane you cannot fly to slow and stall. The power-off or dead stick landing approach is made in the same way as the hover approach was made until minimum speed is reached. At minimum speed and without the power, the 'Giro will start to decend at about a 45 degree angle. The descent will be slow enough to be safe and other than steering, all control is via the elevator. Easing off on the up-elevator will increase forward speed, and with sufficent altitude this control can be used to attain a desired touch down point. Otherwise remember that you are going to touch down practically immediately below where this maneuver started. Obviously, the maneuver should only be attempted over a landing area.

Autogiro landings can be made in two ways. The method just described works well of course, but it does not give you complete control, easily, of the touch down point. Another way is to assume a position for a landing approach a la an airplane, except a bit higher and closer in. Then the 'Giro can be flown down with the engine at low speed using the elevator to control both the altitude and forward speed. When it is about 25 ft. from the desired touch down, the altitude should be about 5 ft. or a little less. At this point the elevator is used to assume a hover position and the engine power is jockied to maintain a descent to the chosen spot. This last portion of the approach will be at a steep angle and the landing roll-out will be practically nil. It should be obvious that with a bit of practice and confidence in your equipment it is possible to fly from very restricted areas as both the takeoff and landing approaches can be steep enough to clear even high obstacles.

I am sorry to say that I have not fully investigated the Autogiro's ability to perform all aerobatic maneuvers, my main reason being limited flying time and the considerable enjoyment I have had just doing the "different" things that a 'Giro is capable of. It is nothing to spend a whole flight just enjoying the hovering and another flight just shooting touch-and-go landings; they are so different from what we are accustomed to! However, I have performed a great many loops with no problem, and wing-overs are easily done and are very true. With the loops it is important to keep them open, as by so doing you keep a smooth flow of air past the rotor. Get them too tight and the wing can block the airflow past the rotor, and as a result the blades can start flapping. The wing-overs are neat because as the apex is reached the 'Giro is hanging on the rotor which still maintains its lift and rudder steerage still remains positive. With a bit of practice, it is possible at the apex to just about spin the fuselage around the rotor axis.

I can see no reason why all other maneuvers are not possible providing that the 'Giro is flown through them properly. They obviously would have to be considered to be of the "stunt" variety as in no way could you expect a machine of this caliber to be capable of precision-style maneuvers. The important thing to remember in ALL maneuvers is that the rotor requires a clean and positive airflow through it. Therefore forward speed should always be maintained and the model should never be put into a position where the wing can block out the airflow through the rotor.

If you have followed through to this point you should be completely aware of the considerable amount of time which I put into the development of this Autogiro. To say the least, for my part, I feel that the results are worth every minute of the time spent. I cannot recall ever having gotten so much enjoyment out of what is very definitely a NEW AND DIFFERENT way to fly. If you are a sport flier the simplicity of this machine should appeal to you and it will certainly make you the center of attention at any flying field. It also could make it possible for you to operate from limited area flying spots that would be impossible for a regular airplane. I can say that much of my test flying was done from a spot from which I would never attempt to fly an airplane. In any event, if you have the urge, give a 'Giro a try; I am sure that you will never regret the resulting enjoyment which a 'Giro offers! ■