GYRO FALCON

By William L. Lehn

Author with original 2-bladed and final 3-bladed dual rotor Gyro Falcons.

If you want something different and exciting, try this Gyro Falcon. RCM did, and it's everything Bill Lehn said it is!

Materials List

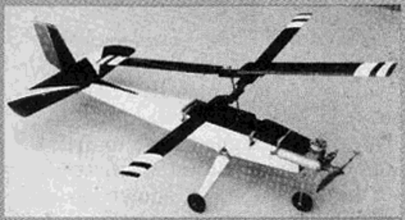
2 — 1/4" x 1/2" x 36" Balsa
2 — 1/4" x 1/2" x 36" Spruce
2 — 1/4" x 1½" x 36" Balsa
2 — 3/8" x 1/2" x 12" Maple
1 — 1/8" x 6" x 12" Plywood
1 — 2" x 2½" x 6" Balsa Block
8 — 3/16" Wheel Collars
8 — 4-40 Blind Nuts
8 — 1¼" 4-40 Bolts
1 — 3/16" Music Wire
1 — 3/16" I.D. Brass Tube
1 — 1" x 7" x 3-6" Pine
Materials for Jigs

3-channel radio
.35-.45 Engine
Wheels, glue, misc. balsa
Carl Goldberg Falcon 56

Is it a bird? Is it a plane? Is it a helicopter? No, it's an autogyro. Or is it autogiro? Webster says it's Autogiro, a trademark for a type of aircraft, heavier than air, in which the wings are supplemented by a system of revolving blades hinged to a vertical shaft. A giro is a type of aircraft bearing the trademark Autogiro. Well what's a Gyro Falcon? By definition (the author's) it's a Carl Goldberg Falcon 56 with the wing replaced by a twin rotor system that provides the lift. Autogiros are not new nor is this approach. In fact, the highly successful twin rotor R/C Autogiro by Skip Ruff started out as a Falcon 56. Well if Skip Ruff has already had a successful twin rotor R/C Autogiro,

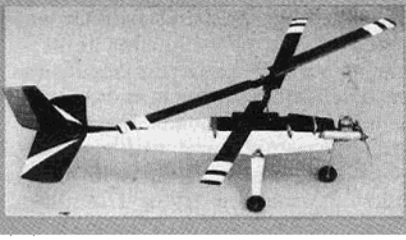
ABOUT THE AUTHOR

William (Doc/Bill) Lehn (AMA 25874) was born in Spring Valley, Illinois, in 1932. Attended U. of Illinois from 1950 to 1954, and the U. of Rochester in New York, from 1954 to 1958. After spending three years with du Pont in Wilmington, Delaware, he and his family moved to Dayton, Ohio, where he has been employed at Wright-Patterson Air Force Base, home of the Air Force Museum, for 26 years as a Materials Engineer working with material for aircraft and space craft and is currently active in the Star Wars area. Interest in modeling began in grade school and has continued through the years. He is a member of the Buckeye Aero Squadron Show Team, and flies all of the trash type aircraft such as flying saucers, irons and flags. He also is an active member of the WORKS club (Western Ohio Radio Control Society of Dayton).

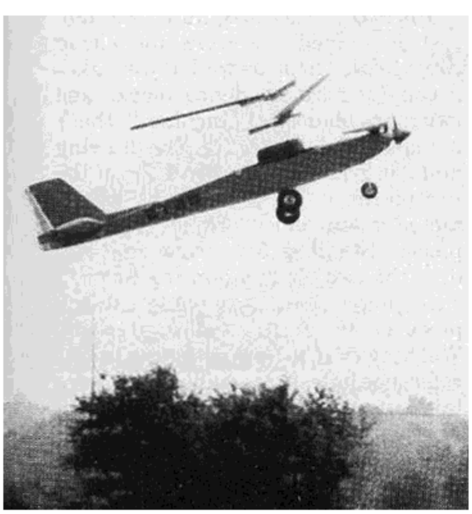


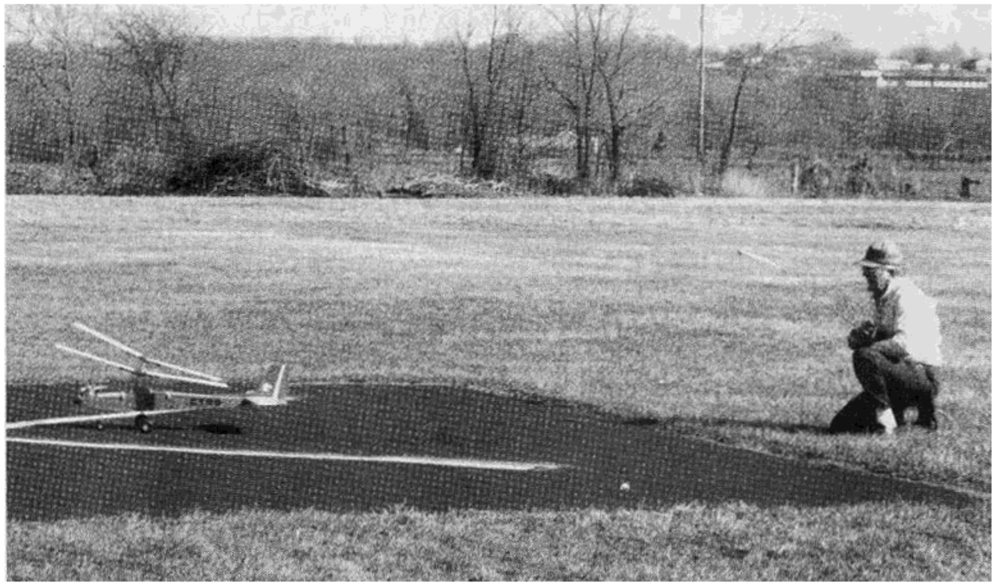
GYRO FALCON

Designed By:
William L. Lehn
TYPE AIRCRAFT
R/C Autogiro
ROTOR DIAMETER
38 Inches
ROTOR BLADE CHORD
2½ Inches
ROTOR LOCATION
Two Coaxial & Contrarotating
2 or 3 Blades Each
ROTOR AIRFOIL
"Eyeball" Clark Y
ROTOR DIHEDRAL (each blade)
5 Degrees
ROTOR SHAFT
10° Negative to Shaft
ROTOR BLADES
5° Negative
AIRCRAFT PROPER
CG Falcon 56
REC. ENGINE SIZE
.35-.45
LANDING GEAR
Tricycle or Conventional
REC. NO. OF CHANNELS
3
CONTROL FUNCTIONS
Rud., Elev., Throt.
BLADE AREA
Total Blade Area
2-2 Blade Rotors 180 sq. in.
2-3 Blade Rotors 270 sq. in.
BASIC MATERIALS USED IN CONSTRUCTION
Rotors .... Balsa & Spruce
Rotor Head .... Maple & Ply
Wt. Ready To Fly .... 76 Oz. (4 Lbs. 12 oz.)



Descending for a landing. Near vertical descent possible in a light breeze. Adjustable mount and 3-bladed rotors shown in this photo.

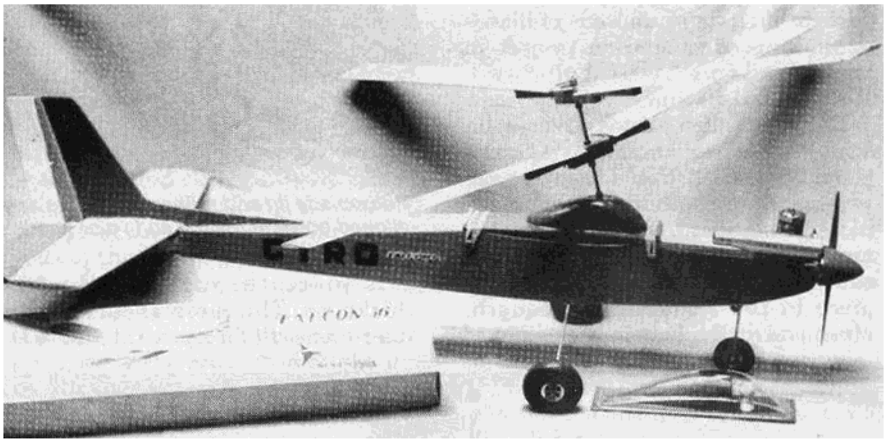




Rolling down the runway for take off. Fast shutter speed has stopped the blades in action.

what's new? Well Skip's giro has two separate independent rotors mounted on the outboard ends of an erector set type of truss. A total of six blades are used and there are two types of blades, two vertical shafts, and two rotor mounts. It's just not the thing that a lazy modeler would like to tackle. Lazy? Basically I'm lazy. Aren't we all.

Helmut Meyer's Super Libelle R/C autogyro (RCM Nov. '77) used coaxial twin rotors but the blades were a construction project in themselves, not to mention the work to make the rotor heads. Dave Larkin had only a few problems with his twin rotor DB autogyro from an English kit but it was similar to Ruff's with two

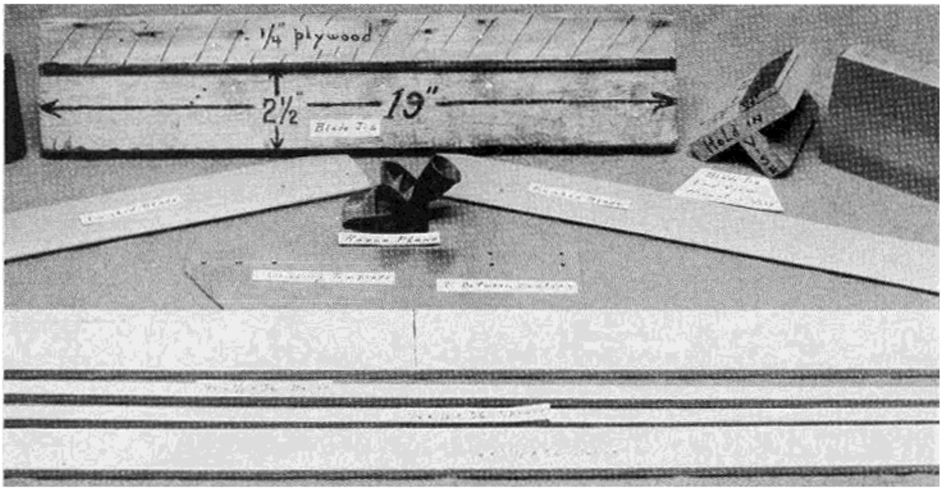


Gyro Falcon 56. Wing mount with pilot and canopy add to overall appearance. Extra area on rudder and elevator required at slow forward flight speeds. Main shaft set at negative 10 degrees from vertical. The original mount shown in this photo was not adjustable.

As they say, KISS (Keep It Simple Stupid).

If one takes a look at some of the references in the model magazines, most of the descriptions of R/C autogiros to date have been anything but simple. A few examples are taken from the references listed at the end of this article. W.J. Kuhnle asks, "Why is it that model giros invariably have wings? If R/C helicopters work properly why shouldn't autogiros?" Now thanks to Mr. Kuhnle's painstaking development of the proper "head," they can. Georges Chaulet closes his interesting article with, "Well, I hope I did something to debug the Autogyro problems, and avoid your having to break several hundreds of rotor blades."

separate rotors at the ends of outrigger booms with two types of rotor blades. deBolt's R/C Autogiro featured flapping blades but was flown and trimmed out as an airplane before the rotor was installed. The flapping head involved a little more work than I am inclined to tackle as well. R.W. Brown described an interesting series of experiments with model autogyros, most of which were free flight except for a final twin rotor rudder only configuration, again with two rotor mounts. For a really complete rundown of real autogiros take a look at George Townson's new book, "Autogiro." One of the fellows on our show team just received a new Wallis Autogyro kit. *(Editor's note: See Don Lowe's column in the*



Rotor blades are easily fabricated from balsa and spruce. Shaping with razor plane and sanding blocks is a snap if you use the simple vice mounted jig.

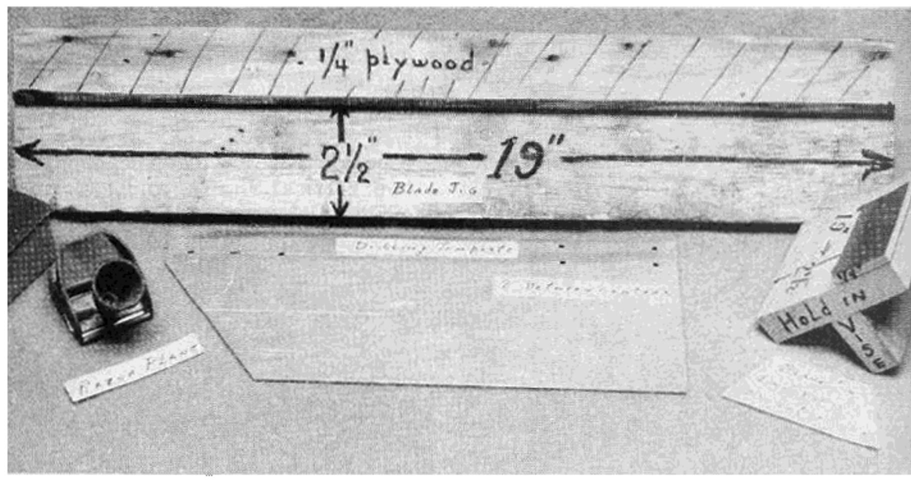
September '86 RCM on this aircraft. Don says it flies more like an airplane than like a helicopter.) It takes a machine shop to make a rotor head like that. It really looks impressive but has all the looks of a helicopter kit when you look at the rotor head and hardware.

Well Charlie, how does one make a **simple** autogiro without all of the effort of making the proper head and without breaking hundreds of blades or making each blade a project in itself? Read on.

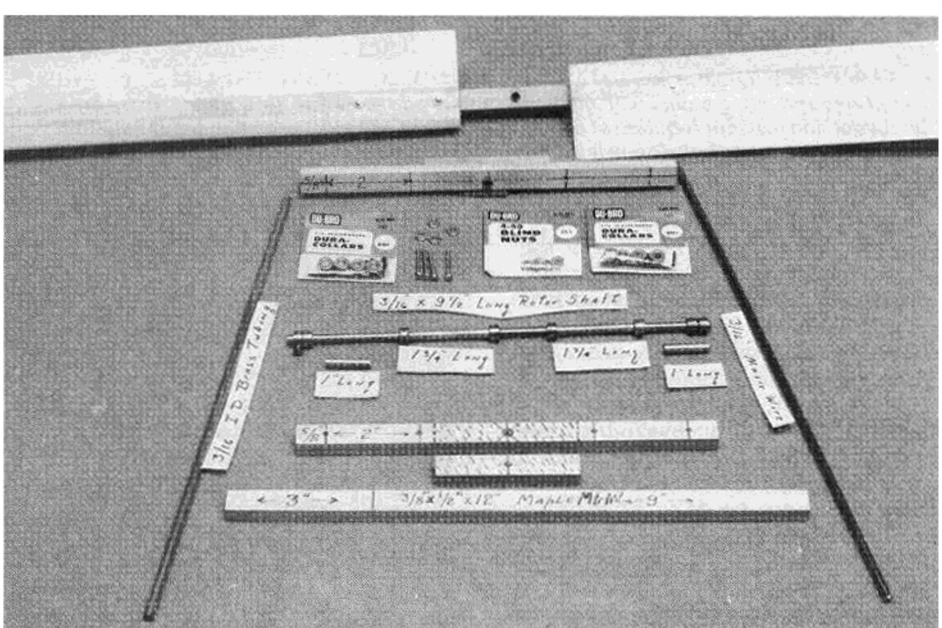
Rotor Heads

The plans and photos give you a complete description and layout for a simple rotor head. You'll need to make two but they're both the same. Take a piece of standard 3/8" x 1/2" x 12" maple motor mount stock. Mark and cut off a 3" piece. Center and glue this piece to the remaining 9" length. Mark and drill a hole in the center of this piece through the double thickness. This hole should be an interference fit for a piece of 3/16" I.D. brass tubing 1" long. This is probably best done on a drill press because the alignment of this hole will determine how true your rotor will run.

Now is also a good time to drill the blade mounting holes. Drill to clear 4-40 bolts located as shown on each end of the 9" long mount block. I suggest you make up a drill template. Mine is a sheet of aluminum with two holes exactly 2" apart. Carefully align with one edge of the mount and set in 1/2" from the end. It can be used to mark the location of the holes or, better yet, as a drill guide. This way all of your holes in the blades, incidence blocks, and rotor heads will line up. Press in the 3/16" I.D. brass tube for the rotor bearing and carefully flare the ends to prevent it from coming out of the maple block. The end of the bearing sticking out should be filed or sanded flat. It is the bearing surface for the finished rotor head. Repeat this process and you now have the two rotor heads. For greater ease of assembly and utility, insert 4-40 blind nuts in the bottom of the arms. Check the fit of the main bearing on a piece of 3/16" music wire. The rotor head should spin freely. If it doesn't, now is the time to free it up with a little du Pont white or similar rubbing compound.

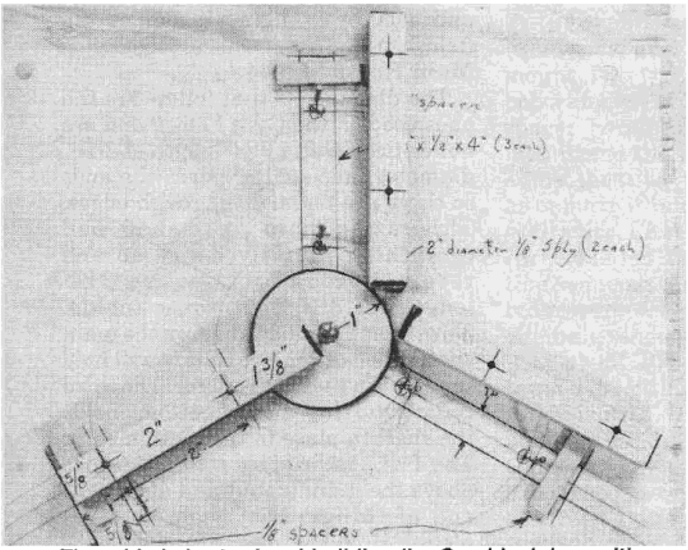


Rotor blade jig and drilling templates make duplication of blades, and drilling accurately aligned holes in blades and rotor heads simple and accurate. Materials of construction are not critical.

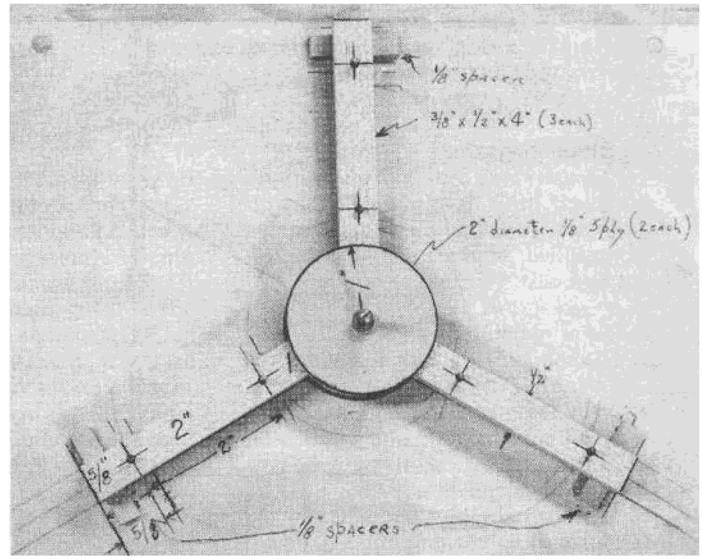


Two-bladed rotor heads are simply fabricated from standard motor mount stock and hardware available at your local hobby dealer. No fancy tools required but a drill press is handy.

Since this was originally written, I've developed a simple and cheap three bladed head as well. It just takes a couple more incidence blocks and two more blades per "incident" (that's a crash) to keep it flying. The drawing and pictures show the details. Cut the two pieces of 3/8" x 1/2" x 12" maple motor mount stock into six equal 4" pieces. Starting 5/8" from one end, drill the two blade mounting holes in each piece. A jig was made using a piece of 10" x 10" x 3/4" plywood. Working from a 7/64" diameter center reference hole, three radial arms were laid out on 120° centers. Locations of



Three-bladed rotor head building jig. One block in position on lower ply disc. Correct positioning ensured by alignment pins, 1/8" ply spacers, and center 4-40 bolt.



Assembled 3-bladed rotor head ready for removal from building jig.

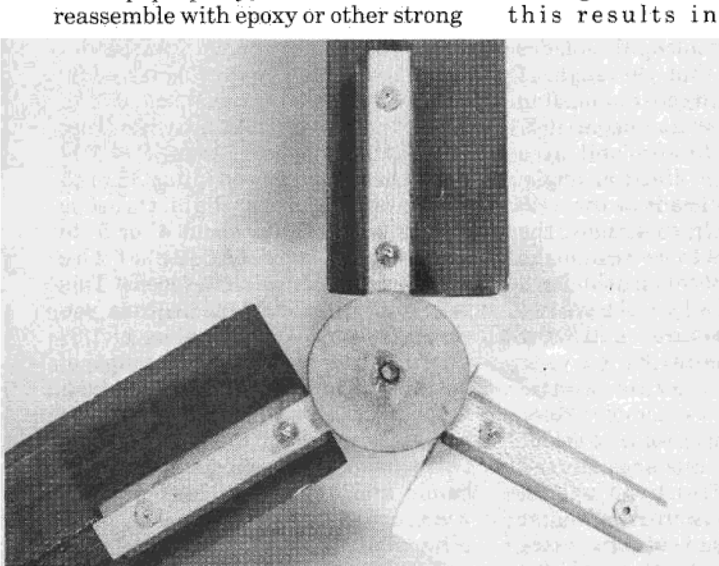
the blade mounting bolt hole pattern were marked on each of the three arms. Then short 6d nails with their heads removed were driven into the board at each of the six bolt hole locations. These index the three 4" blade blocks. With careful work, any of the six rotor blocks will fit in any of the three locations, being aligned by the nails. Four 2" diameter discs were cut from 1/8" plywood. A 7/64" pilot hole was used in the center of each disc.

To assemble the rotor head, use a long 4-40 bolt to locate the 1/8" ply disc exactly in the center of the jig. Three rotor arms are added, keyed in place by slipping them down over the alignment nails or pins. Use small pieces of 1/8" plywood at the outer ends of these arms to keep them level with the center disc. The top 1/8" plywood disc is then added. If things line up properly, disassemble and reassemble with epoxy or other strong glue. Titebond worked well for me. Use a washer and nut on the center 4-40 screw to hold things tightly together until the glue dries. When it's dry, assemble and glue the second rotor head. Appropriate use of waxpaper prevents things from getting glued to the jig itself. When the heads are dry, insert a 7/64" bit in your drill press and use it to align the drill press exactly with the center hole of the rotor head. Clamp the head securely in position, replace the 7/64" bit with the one appropriate for the brass bushing. Drill out the center hole for the brass bushing. Everything is kept in line that way. Flaring the ends of the bushing just a little is in order. Based on the results of my early flight experience, be sure that the bushings are securely glued to the 1/8" ply discs or the rotor head might slip up the bushing and drag on the top bearing wheel collar. As noted below, this results in a slow rotor, asymmetric lift and a potentially catastrophic spiral dive. To date, the rotor heads have survived several incidents. The blades break with little or no effect on the rotor heads. You will need two more blades and two more incidence blocks per aircraft, but those are easy to make (read on).

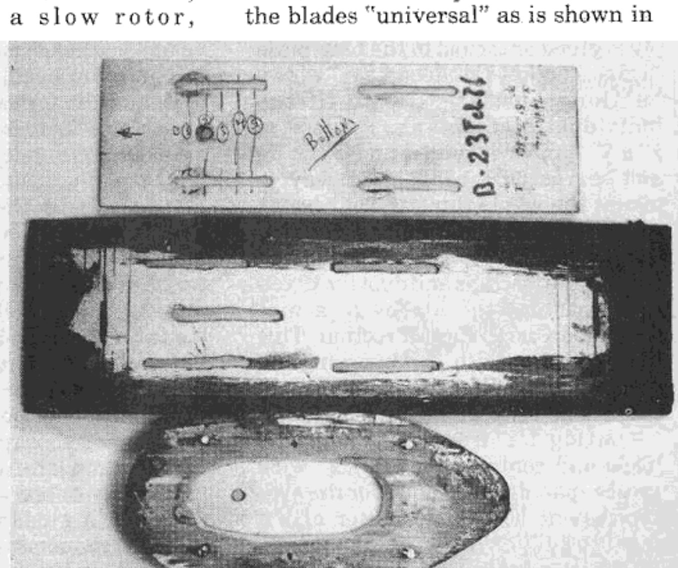
Blades

My original efforts were pretty frustrating. All of the other articles on rotor blades required two types of blades. One set for clockwise (CW) rotation and a second set for counterclockwise (CCW) rotation. A single rotor with fixed (non-flapping) blades won't work since the asymmetric lift will roll the giro to one side or the other and you will have an instant rebuilding job.

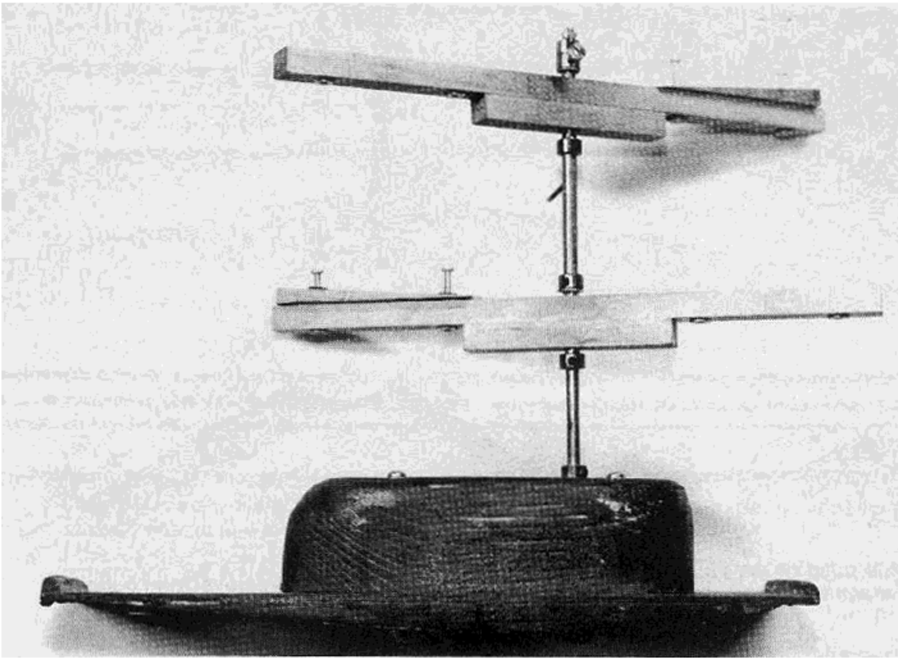
With dual counterrotating rotors, a broken CW blade must be replaced with a new CW blade, and vice versa. The solution to this problem is to make the blades "universal" as is shown in



Lower view of 3-bladed rotor head with blades attached. Note 4-40 blind nuts, brass central bushing, and incidence blocks.



Exploded view of adjustable mount. Marks to keep track of changes in rotor shaft angle of incidence and location relative to C.G.



Assembled 2-bladed rotor heads installed on adjustable mount. Note the wedge shaped incidence blocks.

the plans and photos. Laminate a piece of 1/4" x 1/2" x 36" balsa, a 1/4" x 1/2" x 36" spruce, and 1/4" x 1½" x 36" balsa together to make the two 1/2" wide blade blank. Actually this is enough for two blades. You're going to need a minimum of two blanks for four blades (three blanks for six blades if you go with the three bladed heads), but while you're at it, it probably pays to make up four 36" blanks. This is enough to give you a total of eight blades. When the glue is dry, cut the blanks in two to give 18" blanks. I generally code the blanks for convenience and to have two blades of roughly the same finished weight.

It's jig time again. Make up the blade jig per the sketch. Dimensions are not critical nor is material. I used a piece of regular 1" lumber about 19" long and 4" wide. A 19" length of 1/4" ply is glued or tacked to the base piece to give a pocket 1/4" deep x 2½" wide x 19" long, just the size to fit the individual blade blank. A piece of 1" x 2" lumber is nailed under the jig and serves as a convenient way to mount the whole thing in your bench vise. Then with a razor plane, sanding blocks, orbital sander or what have you, make the chips and dust fly as you bring each of the blades to a nice eyeballed Clark Y cross section. This section works with the big wings so why fight it. When you are finished you should have eight shaped blades.

Starting 1/2" from each end of the blade and centered on the 1/2" wide spruce spar, drill the holes for the 4-40 attachment bolts. The center of the spar is at 30% of the blade chord. Finish the blades with dope, resin, epoxy, or one of the transparent covering films. I recommend the use of a transparent finish so that blade damage resulting from an "incident" will be readily apparent.

Incidence Blocks

The incidence blocks determine the dihedral and attack angles of the blades when they are mounted to the head. A jigsaw, band saw, or table saw will help but isn't absolutely necessary. Using 5/8" to 1" pine or spruce, cut out the incidence blocks as shown in the sawing sequence sketches. The long 5° cut sets up the dihedral angle of the blade. The short 5° angle sets up the angle of incidence of the blades, the other cuts, all at right angles, give you incidence blocks about 3" long. With the drilling template, drill the holes for the 4-40 mounting bolts starting in 1/2" from the narrow edge of the wedge and on the centerline. Remember though, before you start mounting the blades to the rotor head, that the angle of attack of the forward moving/leading edge of the blade is set at a negative 5° by the incidence blocks and at a positive 5° coning or dihedral angle. Washers under the heads of the 4-40 mounting bolts help distribute the loads, or, if you want to, you can make up 1/16" x 1/2" x 3" plywood hold-down pieces. In no time at all you'll have two finished rotor heads ready for balancing and mounting to your newest creation. At this point I usually balance both assembled rotor heads using short pieces of wire solder inserted in the outboard unused mounting holes. Finish up with a touch of CA glue to secure the weight in place. Remember to cut some extra ones if you opt for the three bladed versions. I generally make up extra blades and heads for the convenience and ease of changing blades at the field.

Main Rotor Shaft

The dimensions that follow are the ones used on the Gyro Falcon and are not critical. Cut a 9½" length of 3/16" diameter music wire. Dress the ends so there are no burrs or rough edges. This is the main rotor shaft and everything literally hangs on and revolves around it. Cut two 1¾" lengths of 3/16" I.D. brass tubing. Now, start slipping things on the main shaft. The bottom two collars will hold the shaft in the main mount. The third collar, starting at the bottom, holds the shaft in place in the main mount. The 1¾" spacer gives rotor clearance above the main mount and at the tail end of things. No "boom" strikes please. Hold the spacer in place with the fourth collar. Now it's time for a rotor head (with or without blades). Follow with collar five and the second 1¾" spacer and sixth collar, another rotor head and, finally, the last two collars. I adjust things to take up the slop at the bottom end of the shaft down inside and below the main mount where it doesn't show. It's a good idea to file some flats on the shaft under collars one and two (no sense having the shaft come out in flight). Also at collar number five, above the lower rotor head bearing. (You don't want it sliding up the shaft and binding the top rotor bearing) and, finally, at the very top where the second collar is there for insurance against losing the top rotor. Brass rubbing on brass and a little oil plus polishing of the surfaces will insure that things will spin freely.

Fuselage and Main Mount

Buy a Carl Goldberg Falcon 56. Give the wing parts to a friend and build the rest per the instructions. Don't skimp on the size of the elevators or the rudder. Add about 1/2" to the width of each surface. We will be using a proportional radio control set-up and will need lots of control surface area at near hovering forward flying speeds. About 4° or 5° of down thrust and a good idling 35 to 45 engine are in order. Right thrust is also in order, again about 4° or 5° to counteract the torque of the engine/propeller at slow speeds. This is a high drag airplane in case you weren't aware. Using a piece of 1/8" aircraft grade plywood and a couple of pieces of 3/16" or 1/4" balsa, make a hatch to fit the wing mount. Be sure to make it long enough to attach securely to the top of the fuselage. Use rubber bands and dowels, or your favorite wing mounting method. A solid piece of hard balsa about 2" high x 2½" wide and 6" long is shaped like a "canopy" and attached near the front end of the hatch. Drill a 3/16" diameter hole into

Coming around for a low pass.

the top of the "canopy." Start it at a point 3" to 3½" in back at the leading edge of the fuselage opening (that's pretty close to 25%), and tilted back at an angle of 10°. The main rotor shaft is inserted through this hole and, when everything is ready to go, the main shaft should point to and line up with the C.G. When suspended from the top rotor head, everything should hang slightly nose down. Finish the canopy and mount in accordance with the rest of the fuselage.

Added since this article was originally started after the 1985 Toledo show, is an adjustable incidence and Center of Gravity mount. This is made up of plywood and balsa along with a piece of pine for the spacer between the top rotor shaft mount and the base. It allows you to adjust the tilt of the rotor shaft as well as to move it in relation to the Center of Gravity. First flights using the new three bladed rotor system indicate that reducing the tilt of the rotor shaft reduces the drag and cuts down on the climbing tendency. As initially set up with about 10° of back tilt, the gyro tended to climb excessively under power and had poor forward penetration. This made directional control poor and left little, if any, elevator authority. Throttle controlled the climb and descent. Reducing the shaft tilt to 5° with a slight move to a more nose heavy condition, gave much better penetration and some real elevator authority. In fact, it looks like it will even be able to loop without too much effort. Rotor speed is down considerably with the three blade versus two blade rotors. Aircraft speed did not appear to be affected.

Flying

What's left? What it's all about, flying. If you haven't already, you should balance the assembled rotor heads complete with blades and assure that both rotors turn freely. If things are really free, both rotors will turn in a light breeze with the model sitting on the ground. If you hold it up at a steeper angle of attack things will really spin up and sound like the prop slap from a full scale Cessna 150. Watch those spinning blades because they will hurt and that 3' diameter disc of whirling blades occupies a little more room than that old straight board of a wing. Make sure things are attached firmly. I once had a "boom" strike when the whole main mount stretched the hold-down rubber bands, tilted back, and the lower rotor wiped out the top and both sides of the fuselage. It never even slowed down. If things don't start spinning, check to make sure that everything is free and that the forward moving blades have a negative angle of attack.

As noted above, the three bladed rotor heads tend to rotate more slowly. There may be a bit of blanking of the top rotor by the lower one but, once underway, there is little difference noticeable except for the slower rotor speed.

Don't be afraid to use a lot of rudder and elevator throw. You need the rudder at low speeds and the elevator really doesn't have too much effect unless you have a head of steam up. As noted, at high rotor tilt angles the throttle really tends to control the rate of descent and ascent and I always plan to land with the engine running. With the lower rotor tilt angle, penetration is much better and elevator authority is greatly enhanced.

With batteries charged, radio on, engine running, and everything lined up into the wind, spin up the lower rotor if it's not already turning, followed by the top one. Holding the tail low and increasing the angle of attack seems to get things spinning well and seems to be aided by applying full throttle and getting some help from the prop blast. Release and maintain directional control with the nosewheel and rudder. In a few feet, the blades will be lost in a whirl and things should be airborne. A touch of right rudder is usually in order just as it lifts off, to counter engine torque. Lifting off may be a bit of an understatement because it really tends to jump off when those spinning blades dig in. Tony Fracowiak's comment after watching a couple of take-offs was, "That each one seems to be an experience." It really isn't that bad. Just a hard quick touch (or blip for you old reed fliers) of full rudder with all of that rudder area, will usually straighten things out. With some more flights recently completed, take-off at about three-quarters power seems to work much better. Feeding in a bit of down elevator about the time it lifts off seems to prevent the zoom on take-off and the hanging on the rotors. Instead it lets it lift off and move out more like a conventional model. If things start to veer to either side and you can't correct with rudder, pull back on the throttle. Even with one dragging rotor things generally will tend to settle down and it will straighten out and tend to descend like a kite in autorotation.

As noted earlier, the elevator tends to be rather ineffective unless you

On final, and descending for a landing.

have sufficient forward velocity. Make large gentle turns until you feel things out. Once again, a blip of rudder may be needed to get the turn started. Elevator is not very effective but will lower the nose and let things start moving out flat and level. To descend, head into the wind and gradually cut the throttle. You can make almost vertical descents. At about 6 to 8 feet above the ground, add throttle and some down elevator to cut the pitch-up caused by the added thrust. The Gyro Falcon will slow its rate of descent and touch down with a roll of only a few feet provided you cut the throttle when it touches down. Plan ahead since it takes a certain amount of time for the rotors to spin up and for lift to build (i.e., for a go around).

When flying in a really stiff breeze, it'll hover or you may even lose ground. Watch the application of large amounts of rudder or you'll suddenly find the nose and tail exchanging positions. Due to some laws of physics, the rotors don't change their plane of rotation as quickly as the nose and tail, and what was once a positive lifting rotor attitude becomes a nose down tucking motion. This will accelerate and continue right on down to the ground unless proper action is taken. Don't worry, just haul back on the throttle and it'll settle back into the high drag autorotation attitude and you're back in command. Keeping track of the orientation of things without that big old wing can be a challenge at moments so keep your eyes open. If trouble develops cut the throttle a bit and let the action slow down and get things back in focus.

Hand launching is also possible in a slight breeze. With the engine running at full throttle and the radio on, hold the aircraft up at a steep angle of attack until the blades are spinning rapidly. Make a running launch at a level or slightly nose down attitude with a smooth, firm push.

From RCModeler Sep. 1987

On one of the first flights with the new three bladed heads, the gyro got into a slow circular dive. Cutting back on the throttle didn't seem to help and it spiraled all the way to the ground, breaking a couple of blades when it bounced down. Post flight examination indicated that the upper rotor had slid up on its bearing and was dragging on the top collar, preventing the top rotor from spinning up properly. Thus the asymmetric lift and spiral dive. A metal thrust washer between the wheel collar and brass tube bearing may prevent this from occurring. As they say, you have to keep your rotors spinning evenly. The three bladed rotors cause more drag and mounted at the same angle of rotor shaft incidence, the model tends to want to fly in a nose up stalled attitude unless you feed in and hold down elevator. I say hold, as the amount is more than you can realize with just the standard elevator trim at least on my radios. The three bladed heads seem to autorotate a bit better and the descent is a bit slower than with the two bladed heads.

A word about the engine. Due to the often slow forward speeds, the engine tends to heat up quite a bit so be sure to run things a bit on the rich side and don't go for maximum rpm's. A little rich will save that piston and liner.

Well that's about it. The pictures show you what the final version of things looks like. It also shows you what the original tail dragger version looked like. You don't have to use a Falcon 56 fuselage. If you're one of those fliers who have more fuselages than wings left at the end of the flying season, with a few modifications you can probably have an original Gyro Cadet or Gyro Sky Fox. Just replace the wing on that old trainer or fill in the wing mount area on that old low winger and poke the main rotor shaft up out of the top of the canopy. You'll have to reinforce things a bit, naturally. Just keep the C.G. and rotor and motor thrust angles right. Lots of elevator and rudder area will also be in order. Because of the increased drag, a larger engine is probably in order.

My original comment at this point was, "If anyone has a **simple** way to make a three bladed head I'd like to share it." As you will note, time has passed and I've already worked that one out for us. It should and I believe does make for a better flying machine. Ball bearings would be nice but you'd probably need more than a drill press, at least, for a fancy job. Ball bearings with a couple of simple plywood retaining rings are in the works and it'll probably be possible to get by with just an upper thrust bearing. A tee head with four blades would be pretty straightforward but the weight of the heads may get to be a bit much. A full flying horizontal stabilizer would probably be worthwhile. Scaling up to .60 size or using a nice sounding 4-stroke .40 would also be neat. A handy addition to your work shop and especially useful for such things as the Gyro Falcon is a Universal Protractor Plumb and Level Precision Angle Measuring tool available from Sears. It lets you measure angles of incidence and other angles to about a half degree and was really handy on this project.

Happy flying. □

References

W.C. Hannan has compiled a neat set of references and other information relating to autogyros. They are availble directly from him (final reference).

R.W. Brown, Some Experiments with Model Autogyros, Aero Modeller, Feb. 1975, p. 85.

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