

TWELFTH EUROPEAN ROTORCRAFT FORUM

Paper No. 1

SPANISH CONTRIBUTION TO ROTORCRAFT DEVELOPMENT
HOMAGE TO DE LA CIERVA

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Doctor of Economics

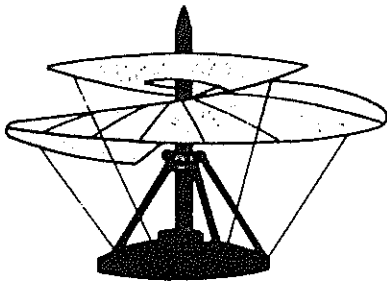
First of all I wish to beg your indulgence as English has been a late vocation for me, and I am going to tell this story a lot worse than I should have wished.

THE WORLD BEFORE LA CIERVA

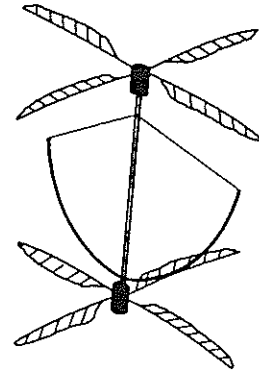
The helicopter (from the Greek HELIX, spiral and PTERON wing) is conceptually older than the aeroplane, although its practical existence came later. It was not simple to arrive at it, as nothing has been simple when passing from the world of the imagination to that of reality. The human being, as observer of Nature, always watched with delight the flight of birds, the fall of sycamore seeds or the self rotation of the acanthus leaf. Many luckless attempts tried to beat gravity by putting into the air a mass equipped with a lifting propeller using ideas from the ancient civilisation of China. LEONARDO DA VINCI (F-2 air screw), LAUNOY and BIENVENU in 1784 (F-1 two bladed toy), G. CAYLEY (F-4 air galley), PHILLIPS in 1842 with his steam propelled rotary wing airship, PENAUD in 1870, ZENKER in 1900, and G. DAVIDSON (F-5 gyropter) struggled with gravity and their ungovernable contraptions. CH. RENARD in 1904 already had ideas about the articulation of blades, R. HAFNER had the idea of the change of pitch and G.A. GROCCO patented the cyclic control.

The brothers LOUIS and JACQUES BREGUET flew the GYROPLANE (F-6) in 1907 which had 32 lifting surfaces (578 kg) and PAUL CORNU flew his free-flying device in 1907 at a height of one foot for 20 seconds (F-7). Also in pre-revolutionary Russia ANTONOV and YURIEV made their attempts, the latter even with a tail rotor.

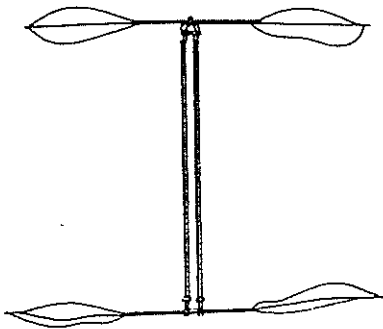
The world before La Cierva



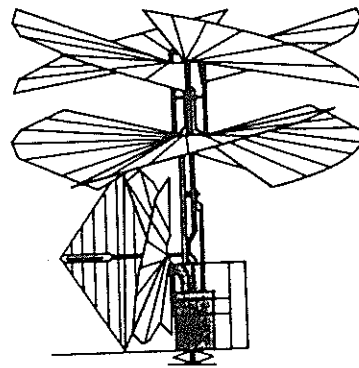
1493 - Leonardo da Vinci



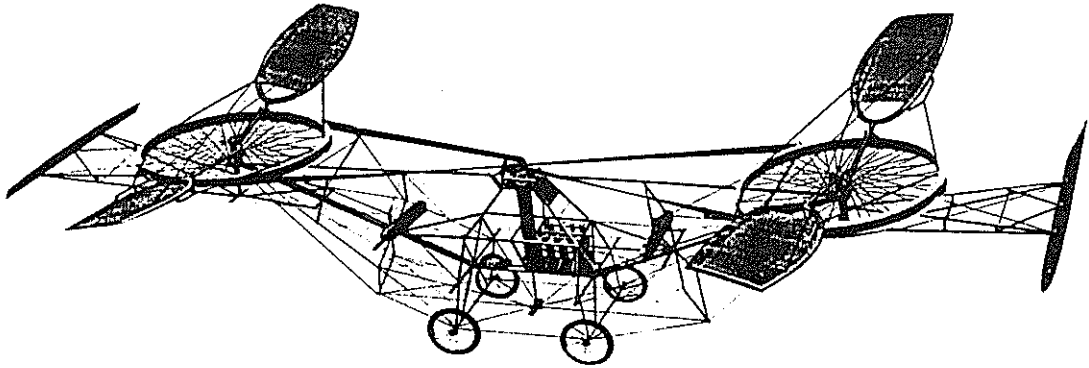
1784 - Launoy and Bienvenu



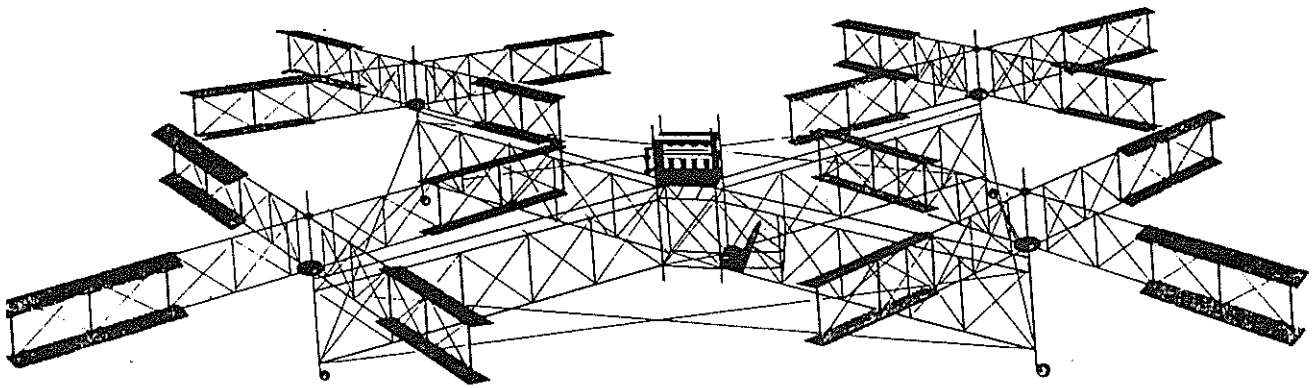
1870 - Penaud



1861 - d'Amencourt



1907 - Paul Cornu



1907 - Louis and Jaques Brequet

In Spain the Marquis of PESCARA flew a machine at a speed of 8 knots between 1919 and 1923.

In 1924 OEHNCHEN maintained his machine in the air for 14 minutes and advanced one kilometre in 7 minutes and 40 seconds.

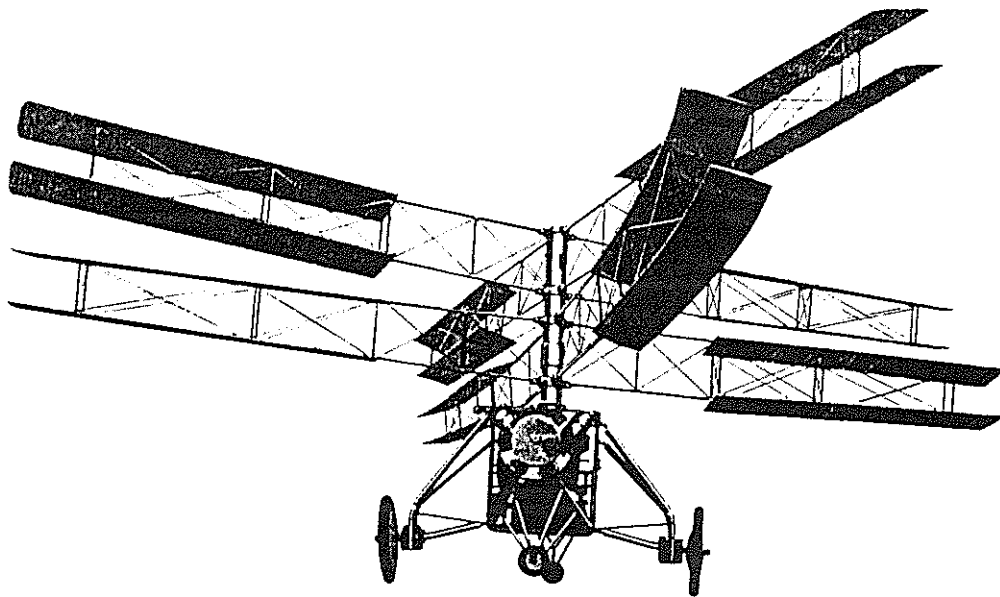
These were the performances of what we could call the world before la Cierva. Too many problems to solve at the same time.

SEVEN STAGES IN LA CIERVA'S INVENTION

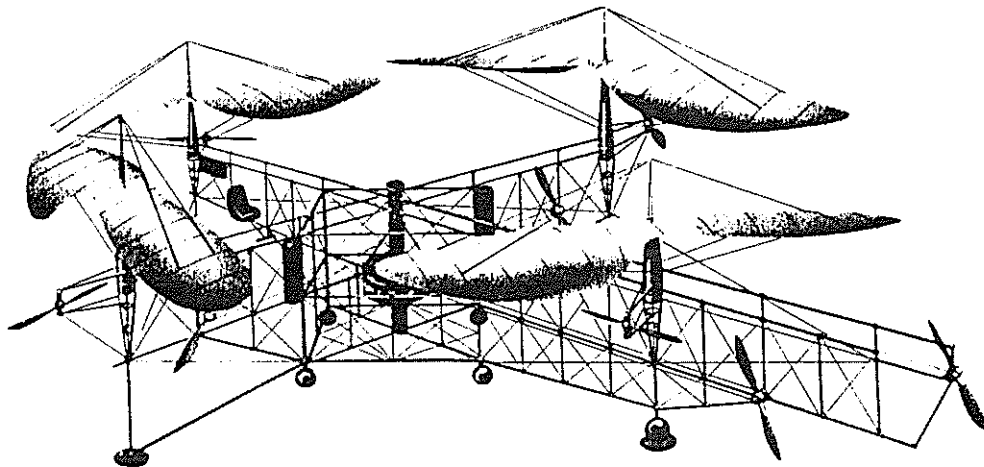
The helicopter took 30 years from its beginnings to its practical achievement in 1937 by HEINRICH FOCKE. La Cierva conceived his autogiro and made it in four years. This is far below the period of maturity of an invention of this nature, and that is why he was an extraordinary man. Born in 1894, he died prematurely in an aviation accident at the age of 41.

At the age of 17 he had already constructed his first natural aeroplane, the BCD 1 or "CRAB". He entered the Higher School of Civil Engineering seeking the highest level of mathematical and scientific knowledge at the time, and we are talking of 1913, however his vocation was not civil engineering, but aircraft. In 1919 he designed a three-engined plane for a military contest, but on July 8th the test pilot dived it and crashed. That marked La Cierva for the rest of his life because his constant dream was to seek a safer alternative to the fixed wing aircraft. According to his friend and collaborator Dr. BENNETT he imagined wings which would move in relation to the fuselage without receiving energy from the engine. This way he arrived at the self-rotating vertical axis rotor with a slight positive pitch.

Prepared to put it into practice, in 1920, he built the C-1 with two coaxial rotors rotating in opposite directions, the top one to the right and the bottom one more slowly to the left. With considerable asymmetry of lift, this made it turn over to the right.



1924 - Pascara



1924 - Oehmchen

I have always wondered whether La Cierva commenced this process methodologically, by applying the "ceteris paribus" hypothesis, i.e. keeping the fuselage, engine and propeller constant and introducing a single element of variation and not varying at elements at the same time, as those who went straight for the helicopter did.

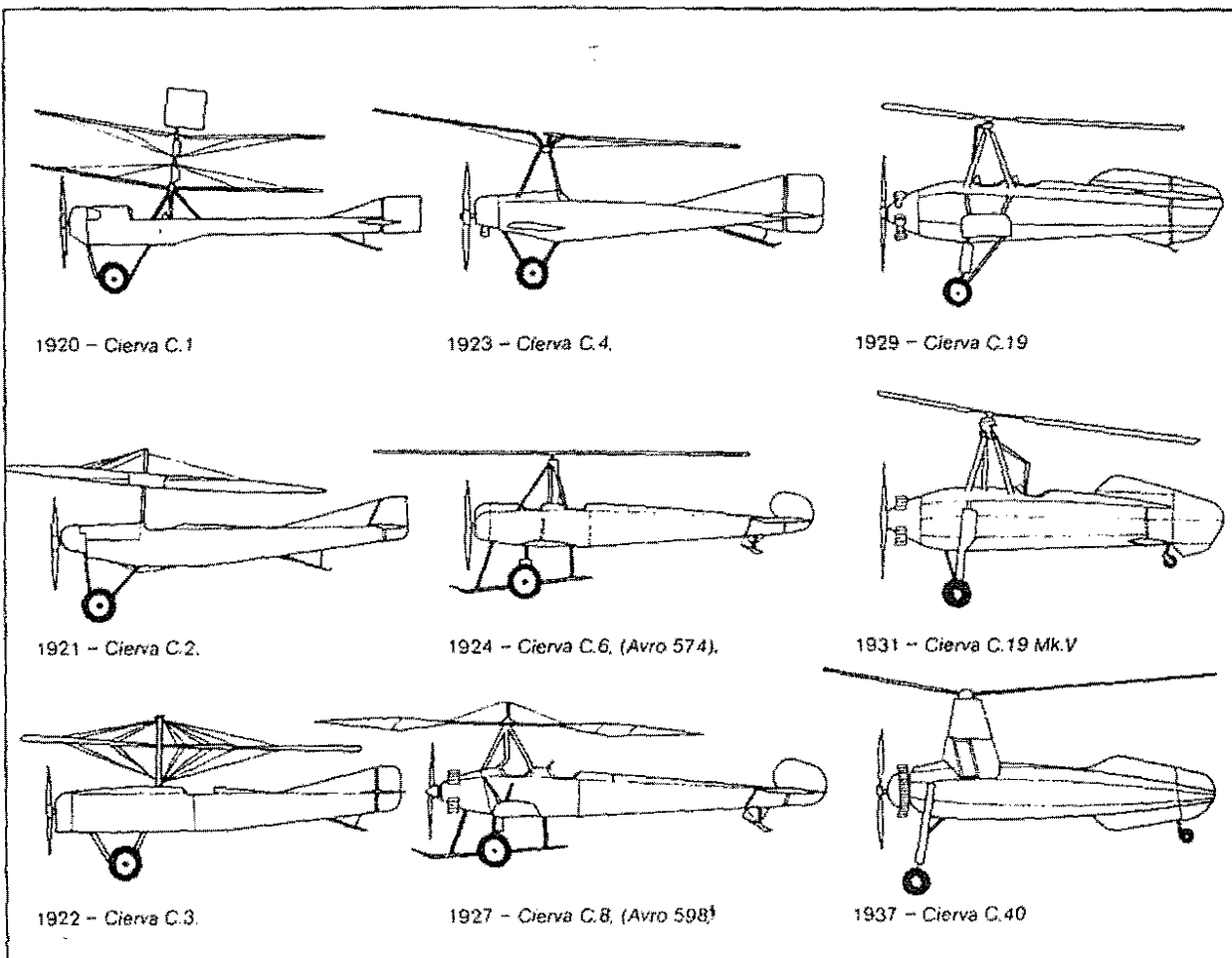
Nobody has been able to give me a categorical answer, but it seems that it was not so. The fact is that La Cierva took out Patent 74322 on self-rotation as a means of lift.

The inventor observed that the receding blade worked with a greater angle of attack and lower aerodynamic speed than the advancing blade and tried to centre the resulting lift of the complete rotor by means of a new distribution of chord and profiles and also different angles of pitch along the blade, arriving at a symmetrical profile with a high negative torsion. In his trials he arrived at the "compensated" C-2 in March 1921. While the materials were supplied, he built the three-bladed C-3. In the C-3 he tested a lateral control system based on the fact that the compensation required a different pitch at any given speed. If the pitch was altered, the resultant force would move off-centre. The device continued turning over to the right (someone said that this was because its inventor was a conservative member of parliament). The C-2 introduced five blades and a second rotor in 1922, but it still turned over.

2. Flap Articulation

The problem was not solved and La Cierva built a flying model and after observation he drew the conclusion that the defect was due to a lack of flexibility of the blades, and he decided to introduce a flap articulation as used in metal bridges on ball and socket joints.

Là Cierva - Autogiros



Thus he built the four-bladed C-4, with a system for tilting the rotor to the right and left, which turned out to be very hard and was thus replaced by a pair of ailerons fitted to a transverse beam. On 17th April 1923 with Lieutenant GOMEZ SPENCER at the controls, it made a free flight at a height of 8 metres. On 31st January it flew for 3 minutes in a closed circuit of four kilometres, 25 metres above the ground, at GETAFE (the first real flight of a rotary wing aircraft).

In 1923 La Cierva built the C-5 in CUATRO VIENTOS, and the tests were passed to the Military Aeronautical Service because his finances were exhausted.

It was followed by the C-6, C-6 b and C-7 in 1924, and LORING made a flight from Getafe to Cuatro Vientos. A year later, in 1925, the C-6 was demonstrated to King ALFONSO XIII and was taken to FARNBOROUGH for trials. In 1926 it was tested at VILLACOUBLAY (France) and the 'LA CIERVA AUTOGIRO COMPANY LTD' was established in London in March.

Technically however, the results were mediocre and the inventor increased the pitch of the blades from 20° to 4-50°, using auxiliary fixed wings to unload the rotor disc. The manufacture in England was entrusted to A.V. ROE & CO. (AVRO). La Cierva was the owner of his Patents and had relations in Spain with LORING (now AISA) and the Military Aeronautical Service. From the deformation of the blade attachments La Cierva observed that a new articulation should be introduced.

3. The lead-lag articulation

In Farnborough GLAVERT said that based on pure aerodynamic theory the autogiro could not fly and COURTNEY, the test pilot who was not fond of it either, suffered an accident on 7th July 1927 with the C-6c employing 4 blades, one of which was lost 30m above the ground.

He was unhurt, but he left the company. La Cierva had meanwhile become a pilot himself and was determined to continue the tests himself when the British AIR MINISTRY suspended the flights until an effective correction of the autogiro could be demonstrated on the ground. After testing a rotor with lead-lag articulation on a test-rig at HAMBLE on 19th May, the C-7 took to the air smoothly.

Autogiros began to be called "Windmills".

With the solution in hand, English autogiros took to the air. He developed the C-8 Mark II in which he crossed the English Channel (La Cierva was by this time an accomplished pilot). Now the aim was to shorten the takeoff run.

4. The Rotor Drive

From 1927 onwards, the rotor was accelerated on the ground by a means of a cable fixed on the lower surfaces of the blades. La Cierva patented mechanical drives which took their power from the engine or from an auxiliary power unit on the ground and he also patented aerodynamic launchers. One of the notable progresses was made with the C-12, using a tail to deflect the air, however this was ineffective. Thus the development of the so-called "scorpion tail" was started. It had a biplane shape and two large vertical fins. This was used up to the model C-19 Mark III, mass-produced in England in 1929. It had brakes on the wheels.

In August 1929 La Cierva got in contact with the PITCAIRN organisation in Philadelphia which had acquired the American rights for the autogiro. There he drafted his "Engineering Theory of Autogiros". PITCAIRN and the British Air Ministry were looking for a practical mechanical rotor drive and tests were carried out on the PC-2 and PC-2-30. After successful testing, the American company started selling autogiros in 1931.

In 1929 A.V. ROE began with the AVRO 620, which was a C-19 in a two-seater version designed under La Cierva. Its rotor had four blades with oscillation dampers for the lead-lags and a scorpion tail. The C-19 Mk I, Mk II and Mk III differed in engine power and blade design. Accelerating the rotor was achieved in the C-19 Mk IV by a power link from the engine to the rotor and disconnection was achieved by a clutch. The first public showing took place at HANWORTH with a C-24 built by DE HAVILLAND and a C-19 Mk IV flying at the same time, the latter with a three bladed rotor mounted on a special ball and socket bearing and a fixed wing of constant chord with ailerons and the ends turned up to channel the air-flow of the propeller. The tail was of conventional form. The landing gear had brakes and shock absorbers.

5. The cantilever bladed rotor

Throughout 1930 and 1931 La Cierva discovered through his theory that the GOTTINGEN 429 symmetrical profile he was using had a very low efficiency. He studied and adopted the RAF 34 airgail. From the C-6 autogiro onwards, the rotors used were four-bladed, but he also tried two bladed and three bladed ones, finding the latter acceptable, except for articulation (the great success of Bell's Arthur Young was achieving a good tow-bladed rotor). La Cierva designed his rotors replacing the suspension cables by support stops and by friction dampers for the lead-lag movement (this was incorporated into the C-24). The C-19 Mk IV and C-24 had cantilever blades.

His calculations showed that a reduction of the disc solidity could be feasible and therefore he could reduce the number of blades from 4 to 3, which was a considerable improvement.

6. Direct Control

Tests were carried out at HAMBLE from 5th to 22nd May 1932 on the C-19 Mk V, with direct control of the rotor, i.e. without using the elevators or ailerons and without the small fixed wings. The SUNDAY EXPRESS reported on this on Easter Sunday 27th March 1932, thereby endangering the sales of the PITCAIRN PA-18 and KELLET K-3, which still used conventional airplane-type control surface.

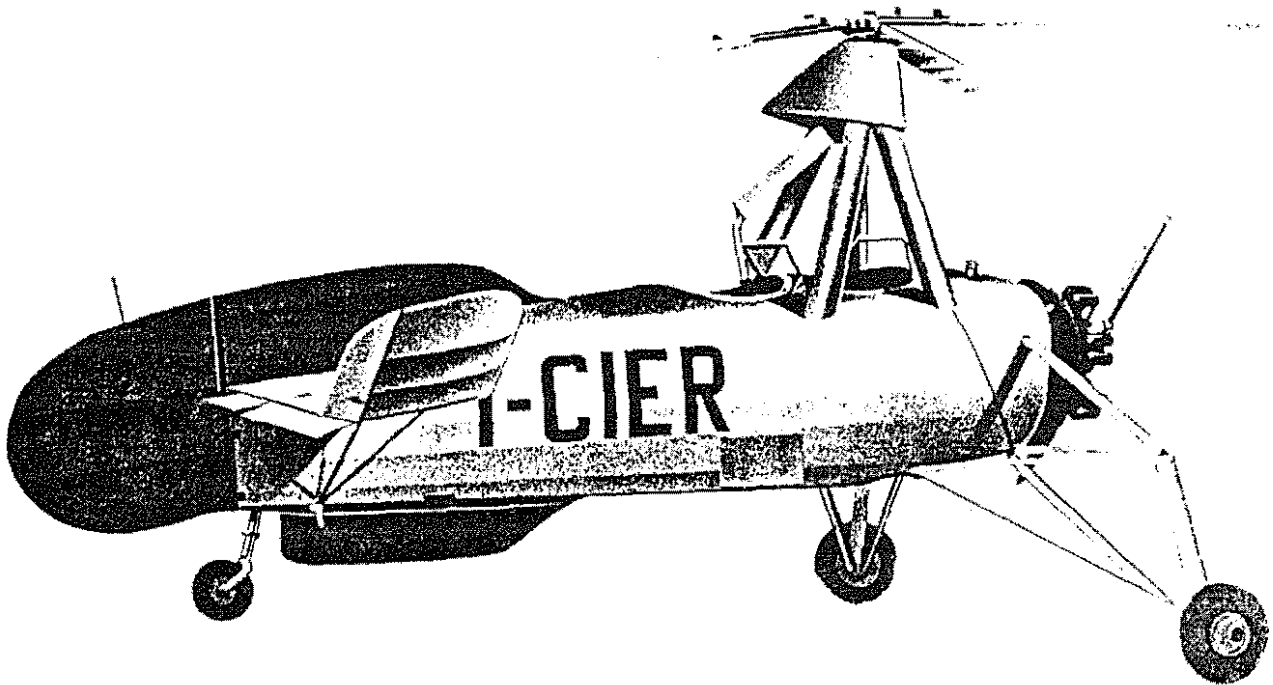
In England G.B. ELLIS, WEIR and OTTO REDER, who had joined La Cierva's team, worked on autogiros. The first direct-control autogiro in mass production was the LIORE-OLIVIER CI-10 designed by LEPERE, however it was not flown. At the end of 1933, autogiros had accumulated 30.000 flight hours.

At the beginning of 1933, after refining the C-19 Mk V, La Cierva had built the C-30, the pure autogiro. This autogiro was controlled through the rotor by means of a joystick, and was able to take off and land in a very short distance. At low speed and in a dive, the performance was excellent, the shock absorbers of the landing gear were capable of absorbing a drop from 2 metres height.

It had a faired-over rotor mast and the main landing gear at the front. To counteract the torque caused by the rotation of the rotor, a long-span horizontal tail-plane was installed with the ends turned upwards by 45°. Floats were fitted in Great Britain. The designer of the direct control joystick was REDER. Also the KELLETT KD-1 manufactured by La Cierva had direct control. Some 150 were manufactured in France and England.

7. Direct takeoff or "autodynamic" rotor

By turning the rotor with the blades at pitch until a speed of revolutions higher than required during flight was obtained and then de-clutching it, the blades adopted a flight pitch and the autogiro jumped to a height from which it was capable of gathering forward speed.



1934 - La Cierva/C30

The C-30 carried a special rotor head with a lead-lag articulation of 25° from the horizontal. This was achieved on 28th October 1935. The blade turned around the lead-lag articulation to rest on the back stop, adopting nil pitch, on declutching an inertia took it to the front stop with positive pitch. The prototype which was provided with an 'alpha-one' jump articulation was the C-30 Mark II two-bladed version. The rotor head called the 'outstanding contraption' had three hinges (flaps with 'delta three' angle to achieve a cyclic variation of pitch in combination with flap; an 'alpha one' negative drive articulation to eliminate resonance on the ground without shock absorbers and the third, 'phi' of direct jump, equivalent to a positive 'alpha-one'). The latter was suppressed. The flap articulation remained with a 'delta-three' angle of $9^\circ 6'$ and the drive one with an 'alpha-one' of -26° . Thus the C-30 Mk III was arrived at, ready in 1936 while WEIR was building the W-3.

La Cierva died on 9th December 1936 when the airliner in which he was passenger, a KLM DC-2, crashed when he was 41. He had promised to build a helicopter, but it is not far-fetched to say that with his invention he contributed more to the development of the helicopter than any of those who devoted their best efforts to it (this is affirmed by Warletta, who has made the most thorough study of the historical aspect of autogiros).

AFTER LA CIERVA

In 1937 the ROYAL AERONAUTICAL SOCIETY gave Juan de la Cierva its Gold Medal. WEIR was the Chairman of LA CIERVA AUTOGIRO, PITCAIRN was on the Board of Directors and Dr. BENNETT also worked in there. The AIR MINISTRY ordered a new prototype, the C-40. WEIR was already making helicopters, rejecting the offer of a licence from FOCKE. In July 1938 the C-40 flew with a 200 hp engine, while WEIR was flying the first British side-by-side torn helicopter of the Focke type (W-5). BRIE, another of La Cierva's companions, commanded the RAF's 529 AUTOGIRO SQUADRON with C-30s which flew some 8.000 hours in the war on radar calibration missions.

From 1943 the La Cierva Autogiro Company, reactivated by WEIR, developed the W-9, W-14 and WII (Air Horse) helicopters. On 13th June 1950 the last named crashed causing the death of the pilot MARSH, another traditional autogiro man.

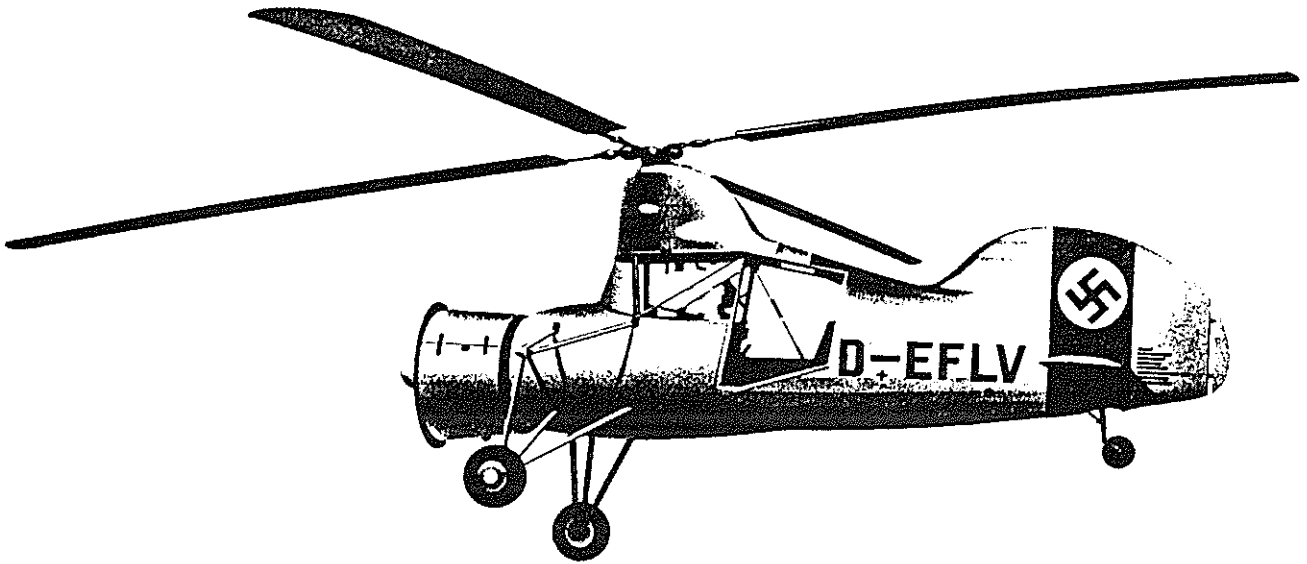
In 1966 WEIR and SHAPIRO formed the LA CIERVA ROTORCRAFT Ltd. which in 1969 flew the CR TWIN (WEIR retired at the age of 83).

Dr. BENNETT in June 1945 took over as Technical Manager the helicopter division of FAIREY AVIATION CO. In 1947 he flew the GYRODYNE single engine helicopter equiped with a small fixed using on the right top of which there was a small antitorque propeller. The rotor control was by inclination of the head, a legacy of the autogiro. In 1948 it gained a speed record with 200 kph. Bennett ended up as the Research Manager of HILLER AIRCRAFT.

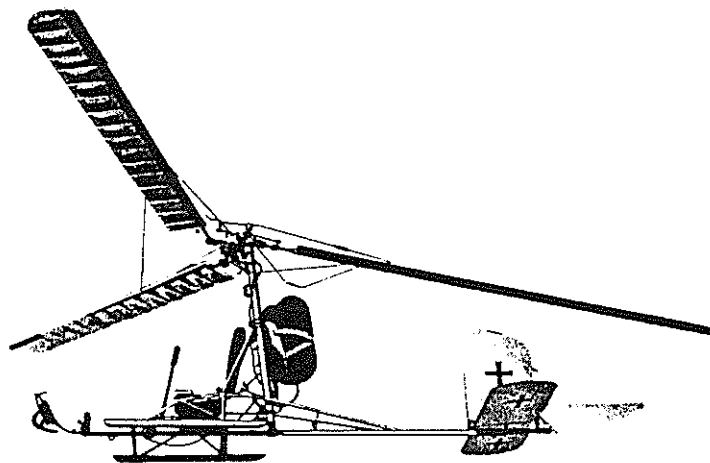
Another man who had an autogiro background, which he never forgot, was FOCKE. In 1937 the success of his autogiro was worldwide. On 10th May ROHLFS made a landing with auto-rotation with the engine switched-off. The Fa-61 beat the altitude record (3,247 m) as well as the speed (123 kph) and range (230 km) records.

Both FOCKE and FLETTNER built helicopters in the Second World War, but FOCKE continued to think of the autogiro when he built the Fa-330 BACHSTELZE in 1942, with a single rotor, no engine, three blades and an inclinable rotor head for observation from submarines.

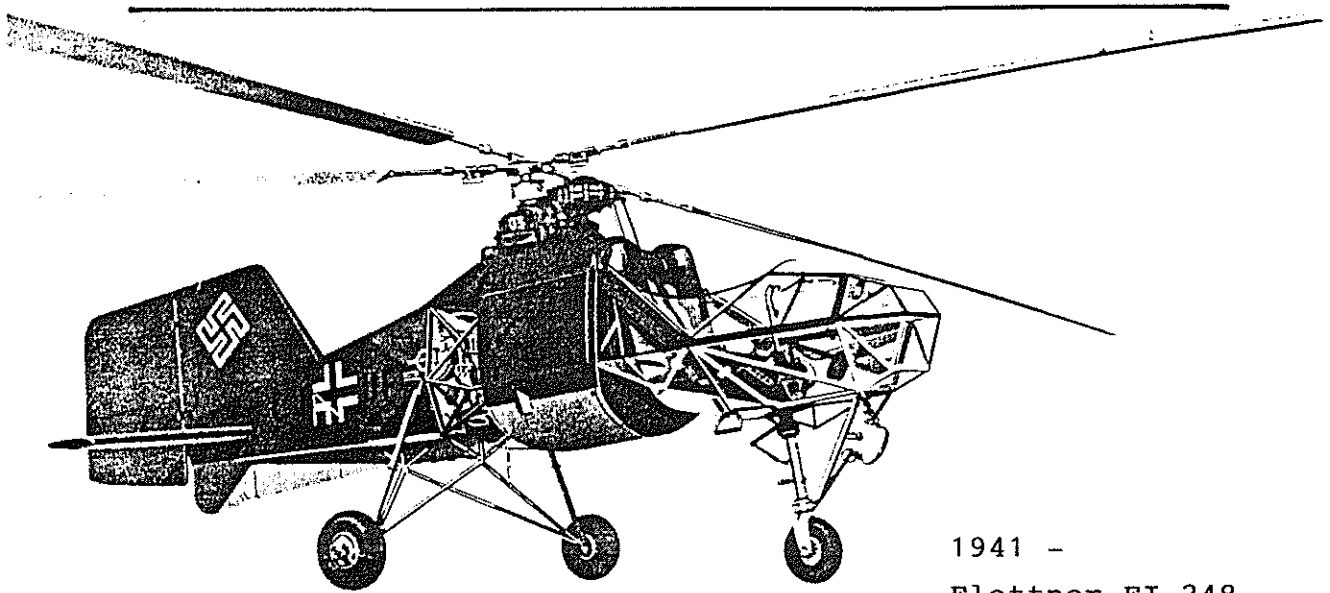
La Cierva had faithful followers in France also. In 1937 France was the country with the highest number of military autogiros and orders increased at SNCASE with the war. During this the SE-700 was developed and it flew in May 1945 with a 350 hp engine and vertical take-off based on collective pitch. FOCKE helped SNCASE to devote themselves to the helicopter, but still twenty years after the death of Juan de la Cierva, LEPERE designed the L-50 GIRHEL as a token of faithfulness to the autogiro.



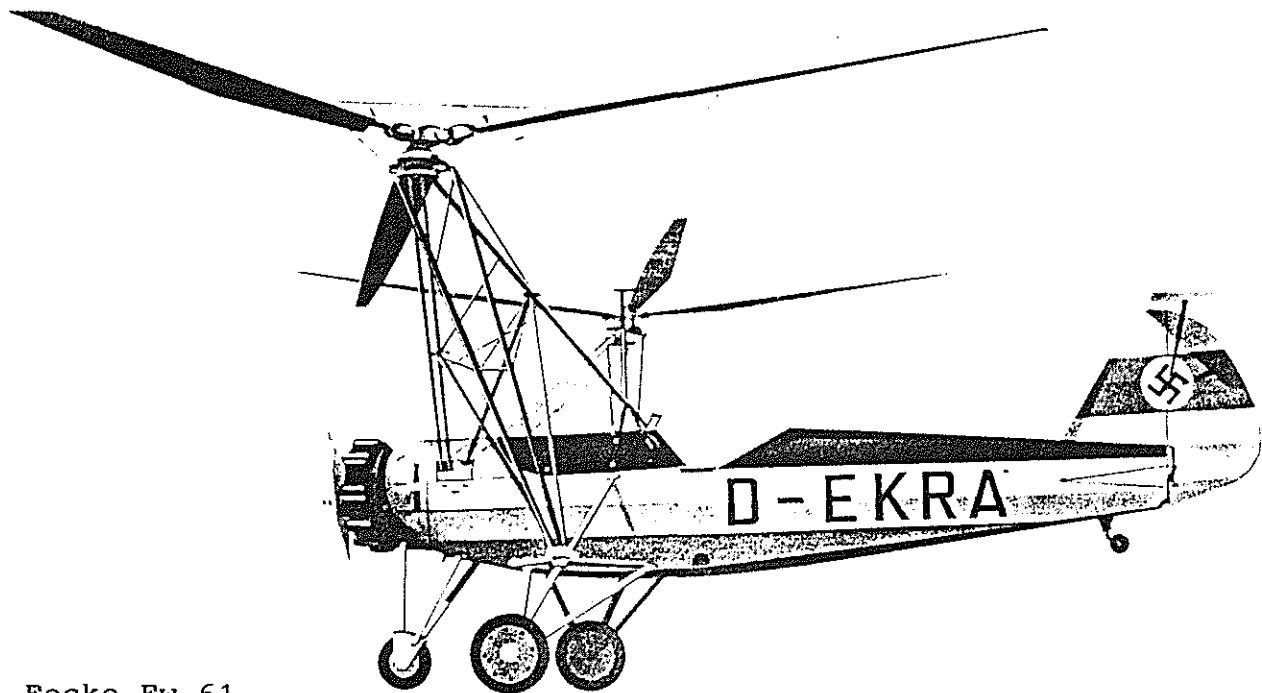
1939 - Flettner FI 265



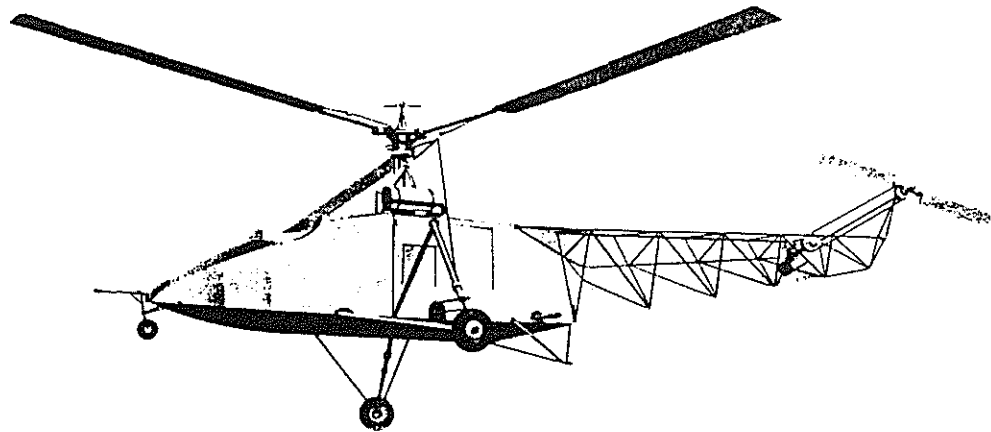
1942 - Focke Fa 330 Bachstelze



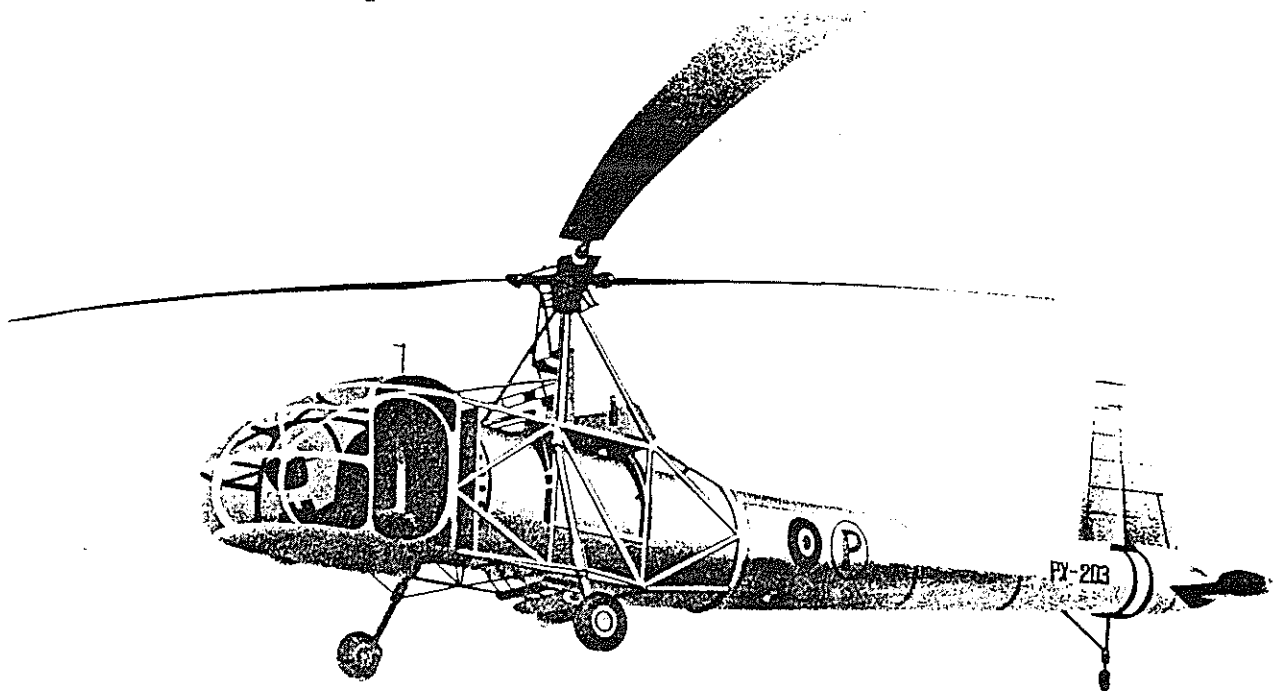
1941 -
Flettner FI 248



1936 - Focke Fw-61



1939 - Sikorsky VS-300



1944 - Cierva W.9

AGNEW LARSEN, who worked in England at the La Cierva Company returned to the USA in 1937 and developed the PA-36 autogiro with a 165 hp engine. The change of pitch for jump takeoff was original, namely by means of a screw through which the blades, from a bottom position achieved by hydraulic retention, passed to a higher one on declutching. It was the most refined autogiro. BRIE, as a Wing Commander in the RAF took off and landed with a PA-39 on the stern of the merchant vessel EMPIRE MERSEY in 1942.

The United States Army gave a boost to the development of new autogiros such as the 300 hp XO-61 with a gross weight of 1378 kg.

In 1942, with PITCAIRN as the President of the AUTOGIRO COMPANY OF AMERICA, the autogiro Patents were applied to the helicopter and they were held by FIRESTONE (G & A AIRCRAFT), KELLETT, and the SIKORSKY AIRCRAFT DIVISION of the UNITED AIRCRAFT CORPORATION. KELLET developed for the Army the YG-1B, YG-1C and the KD-13 postal autogiro to transport mail. While in Germany and Great Britain the first helicopters were made by FOCKE and WEIR, former autogiro builders under licence from La Cierva, PITCAIRN and KELLETT lost the battle to IGOR SIKORSKY in the USA.

In 1939 SIKORSKY made the VS300 experimental machine which flew in 1940. It flew in all directions except forwards and it was even thought to turn the pilot's seat around. But when the problem had been solved, it was better than the Focke Fa-61, remaining in the air for 1 hour and 30 minutes. It remained with its typical antitorque rotor. The Army supported its development.

In 1943 KELLETT flew the XR-8, a helicopter with two geared three blade rotors; 'SYNCHROPTER', the system used in Germany in 1938 by FLETTNER. KELLETT also designed the SKYCRANE.

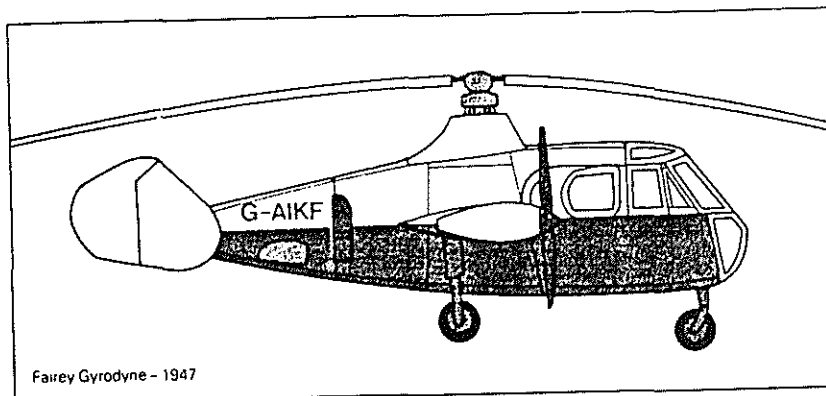
SIKORSKY AIRCRAFT was to purchase a licence from the AUTOGIRO COMPANY OF AMERICA covering several dozens of essential patents relating to rotary wing aircraft.

In Spain at the present time there is no production of either autogiros or helicopters.

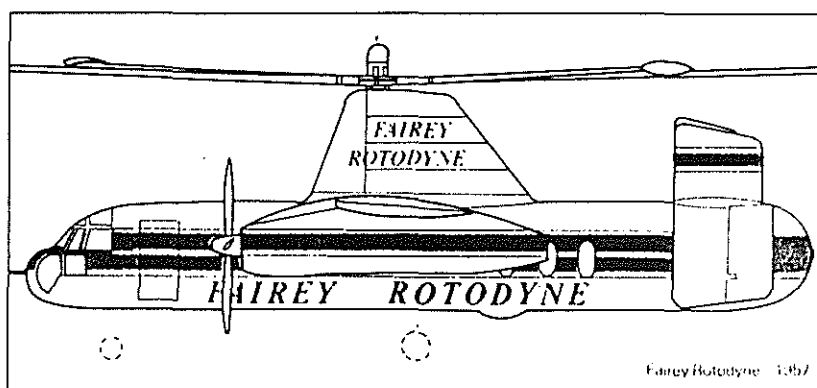
Since the introduction of the MBB BO-105 , built under MBB licence for the Spanish Army Mobile Air Force, the production has been practically nil. In autogiros the AISA company tried some years ago to develop a prototype, the GN, on which one of the sons of La Cierva, also now dead, worked as an engineer. It was provided with four BELL blades with flap and lead-lag articulations, cyclic and collective pitch and vertical takeoff. It was powered by a 300 hp LYCOMING engine. It was destroyed in the tests and the project was suspended.

HISLOP, the successor of BENNETT in the firm of FAIREY converted the GYRODYNE into the JET GYRODYNE with a rotor propelled by jets on the the blade tips. Then he directed the 15 tons ROTODYNE which flew in 1957 with a four bladed rotor of 27.43 m and two NAPIER ELAND 3,300 hp turbo-engines mounted on a fixed wing.

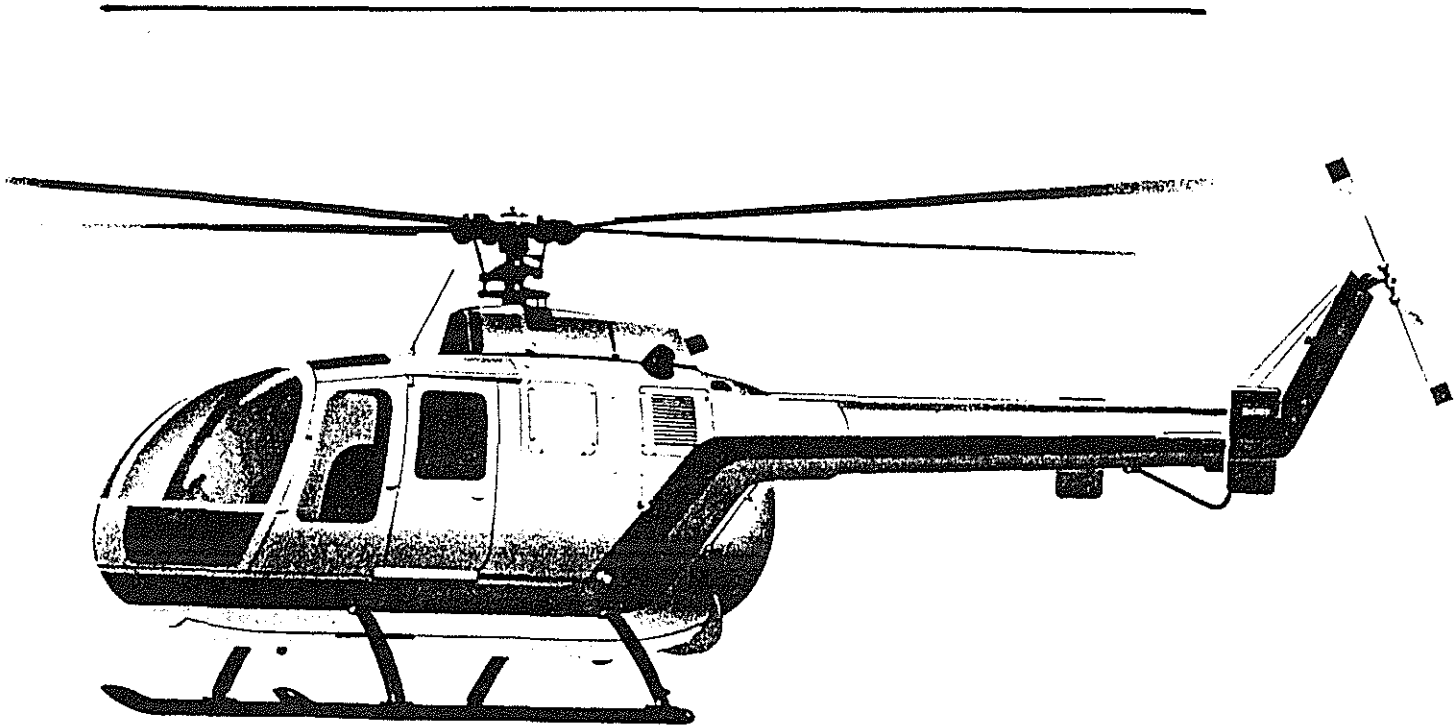
On takeoff and landing it was a helicopter, as the compressors sent air to the burners on the blade tips, which drove the rotor by producing jets. In flight it was declutched and became a fixed wing autogiro. The flight controls were those of an aeroplane, reaching a speed of 309 kph.



1947 - Fairey Gyrodyne



1957 - Fairey Rotodyne



1980 MBB - BO 105

THE HERITAGE OF DE LA CIERVA

To sum up all the previously mentioned, with the weak technical knowledge of an economist enthusiast of aeronautics, we could point out that Juan de la Cierva was the first one to set up the scientific bases that have resulted in the helicopter as we know it now, though just the bases, as the helicopter is the rich offspring of the effort and cooperation of a large number of people. But, Juan de la Cierva discovered the aerodynamic phenomenon of the autorotation and established the principles when looking at a way of substituting the wings of an aircraft to create lift and at the same time preventing stall.

During this research he defined the basic principles of the free turning rotor and the autogiro. During the improvement process of that rotor, Juan de la Cierva gradually introduced concepts and improvements that were to be basic for the development of the future helicopters, as for instance the lead-lag and flapping hinges and attaching the rotor blades in order to lighten their structural load and thus to be able to lighten their weight (Attachments that in their most sophisticated version were to be seen in the helicopters of the 60's).

Likewise, he did the first (at that time surprisingly profound) mathematical studies concerning the aeroelastic performance of the rotor blades, solving with the help of Spanish mathematicians, the corresponding differential equations. Those studies concerning lift and aeroelasticity of the rotor blades were not to be beaten until World War II and the event of computers. Simultaneously with those mathematical studies he did researches into the influence of the different aerodynamic profiles and the shape of the blades concerning their performance, as well as into the performance of the rotor in relation to the number of blades, thus, always bearing in mind his basic objective, which was to bring about a rotor as safe and simple as possible, minimizing at the same time the weight of the unit.

As anecdotal data giving us an idea about his advanced structural calculus (within the parameters of extreme safety) we could say that the apparently complex and sizeable "de la Cierva" autogiro only reached 75% of the weight of an equivalent wing that would have allowed it to fly like a normal aircraft, without profiting from the advantages of an autogiro.

Finally I would like to point out that Juan de la Cierva while researching into rotors of great simpleness, was the forerunner of the modern rigid rotors in which the control and stability were achieved by the controlled flexibility of the new composite materials.

The only thing that kept him from leaping forward in that sense -which would have meant a 50-year-leap-forward in rotor technology- was the fact that at that time the only material available was wood, which does not offer the necessary characteristics for directional flexibility and resistance which nowadays can be achieved with the new fibres of composite material.

This is the heritage of de la Cierva, together with his splendid human frame of mind, his courage, his initiative, and being still very young he became a real leader, originated a new school with unconditional followers who traced the path that he himself would have liked to follow.

THE HELICOPTER IN THE WORLD ECONOMY

On the production side, there is little I can tell you that you don't already know. The 1973 oil crisis together with the other types of crisis affecting Western society led to a decrease in production which will not be reversed until the end of the decade. Helicopter production has alleviated losses in some companies caused by cancellation of airplane orders. From a clear difference in production between the military market and the civil one in 1960 (9500 aircraft as against 2000), in 1985 the ratio is reversed (921 to 2369) and for 1990 the estimate in units and value take us to 875 to 2995 aircraft and from \$ 6088 million to \$ 4144 million.

Investment in R & D in 1985 was \$ 490 million in military and \$ 69.7 million in civilian programmes.

All this is sufficiently illustrative to describe that the 7-8% of total aeronautical production which is accounted for by helicopters, by number of units, the civilian market has acquired its real importance, although in sophistication of equipment and annexed elements, the military market is in the lead.

Of the over 6.000 helicopters distributed among the over 1.000 companies operating in the civilian market, the average size of fleet is 2-6 helicopters, a figure which is found in all continents, the USA together with Canada operate 59% of the total, Europe 22% and Japan, 55% of Asia.

The USA are the major supplier of helicopters in Europe (60%) and the rest of the world (75%). For its part, Europe is achieving an increasing penetration in the American market with its products.

We cannot say that helicopter operator companies are small or ineffective. Out of 624 companies, nine are operating between 50 and 100, 6 companies between 100 and 400 and one has more than 400.

Although offshore activities on oil rigs are outlined as the most profitable, few economic activities escape the helicopter:

- Supply, relief and evacuation from rigs
- Prospection for oil and minerals
- Insect spraying, fertilising and top-dressing
- Fumigation
- Logging
- Extinction of forest fires
- Laying and maintenance of electricity lines, pipelines, etc.

- Public works
- Aerial photography
- Filming
- Mountain rescue
- Rescue on beaches and at sea
- Location of fish swarms
- Operation in civil catastrophes and disasters
- Rescue on the road
- Scientific and sports expeditions
- Executive transport
- Heli-Shuttles between airports
- Ecological protection
- Industrial accidents
- Tourist excursions
- Medical transport of patients and organs.

A long list, increasing as time goes on, of applications, together with others of the public sector of the economy, apart from the armed forces. All this makes us wonder now, why are autogiros not being made?

WHY ARE AUTOGIROS NOT BEING BUILT?

We know that in 1934 Admiral BYRD took autogiros to the South Pole in his expedition, they landed on the decks of ships, directed the traffic in London, transported the mail in Philadelphia from the Head Post Office to the airport. Additionally forest surveillance, advertising, fishing, fumigation, police, oil pipelines and so forth were normal activities for the autogiro.

Furthermore expectations for the production of STOL aeroplanes for takeoff in 500 metres do not appear to be satisfactory and an autogiro, using modern technology, put into production by manufacturers of reputation is something to be considered.

The aim is not to take the worse of the aeroplane and the helicopter, but the best of both worlds at a cheaper price.

Autogiros can do the same missions as helicopters except those requiring hovering, which are a minority, the rest would be completed independently of prepared grounds. This is in the civilian market. In the military market, the same applies for missions of the Army and Security Forces relating to surveillance and liaison.

This makes us think that a correct proportion of the fleets between aeroplanes, autogiros and helicopters would lead to tighter and more affordable costs, encouraging users.

The technical combination of autogiro and helicopter seen in the ROTODYNE of the combination of aeroplane and helicopter demonstrated by the BAYNES HELIPLANE also points to future projects in this direction.

Nevertheless, beating the law of gravity and going against natural laws in a systematic way, means rising costs which are more than proportional in the trading accounts of companies and state budgets. Although civilisation does not move backwards technologically, as you are about to demonstrate brilliantly, to the astonishment of all, on the threshold of the year 2000, convertiplanes will be a marvellous reality, but let us not be naïf. The last economic crisis in history, that which you and I are living through, like the 1929 crisis and all the preceding crises, open our eyes to the exponential growth of the population indicated by MALTHUS and requires us to exercise a wise and balanced administration of resources. Aviation in general is not something elitist, or which is paid for regardless of cost as a defensive weapon; it must be profitable.

BIBLIOGRAPHY

WARLETA J, "Autogiro - Juan de la Cierva y su obra"

WARLETA J, XXI Conferencia Juan de la Cierva

LOPEZ RUIZ, El helicoptero en los sistemas de transporte y defensa

REVISTA FLAPS, Los autogiros Cierva C-19 y C-30

HELICOPTERS AT WAR

ALONSO GULLEN F, Reivindicacion del autogiro (Revista de Aeronáutica)

GARCIA-FRAILE A, La empresa de helicopteros (Doctoral thesis)

MAESO, El GN de AISA (Revista FLAPS)