THE EVOLUTION OF THE BRITISH ROTORCRAFT INDUSTRY 1842-2012

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ABSTRACT

This paper relates the way in which rotorcraft developed in Britain, leading to the growth of an effective design and manufacturing industry. The narrative is divided into five sections, each of which represents defining phases in UK based activity leading towards the development of the modern helicopter:

1. The Pre-Flight Period (1842-1903) This section covers British activity during the period when the objective was simply to demonstrate powered flight by any means, and where rotors might be considered to be a way of achieving this.

2. The Early Helicopter Period (1903-1926). Early attempts to build helicopters, including the work of Louise Brennan, which achieved limited success with a rotor driven by a propellers mounted on the blade tips.

3. The Pre-War Years (1926-1939) This section gives emphasis to development of the gyroplane and in particular the work of Juan de la Cierva, with his UK-based company to develop his 'Autogiro', from which the understanding of rotor dynamics and control was established, and which was to lead to the realisation of the helicopter by others. Although UK rotary wing development was driven by the gyroplane, the work carried out by the Weir Company, which was to lead to the first successful British helicopter is discussed.

4. The War Years. (1939-1945) Rotary wing activities in the UK were very limited during World War 2, restricted to the work carried out by Raoul Hafner with the Rotachute/ Rotabuggy programme and the use of autogiros for the calibration of radar.

5. The Modern Helicopter Period. (1945-2009) This section covers the growth of the four major helicopter companies in Britain which came about after World War 2, namely Bristol (Hafner), Cierva, Fairey and Westland. The diverse projects undertaken by a these companies are discussed. The rationalisation of the British aircraft industry initiated by the British government, leading to the creation of Westland helicopters as the UK's only major helicopter manufacturer, is described. The success of the Westland Group during the ensuing 25 years, brought about by a well founded license agreement with Sikorsky and the development of the Lynx within the Anglo-French Helicopter Agreement is described in detail. The decision to enter the civil market with an aircraft based on the Lynx transmission coupled with a drop-off in military orders, led to a crisis of confidence that the company could survive alone. The argument regarding whether Westland should strengthen its alliance with Sikorsky, or seek a European partner, assumed political proportions. The recovery of Westland was brought about by effective re-structuring,

capitalising upon blade technology, and through successful co-operation with the Italian company Agusta, and was to lead to the formation of AgustaWestland as part of Finmeccanica. A number of British helicopter projects, which were not related to Westland are also included.

1. THE PRE-FLIGHT PERIOD (1842-1903)

An outline diagram of the people and organisations involved in the development of rotorcraft in Britain is shown in Figure 1. The pioneers of the pre-flight period are listed below.

1.1 W. H. Phillips (1842)

As early as 1842, W H Phillips is reported to have flown a 2 lb (0.9 kg) model helicopter driven by steam effluxes from the blade tips with limited success. Power was achieved by burning a mixture of charcoal, gypsum and nitre (which, in the appropriate proportions would be a form of gunpowder!). The inventor described the event as follows:

> *"All being arranged, the steam was up in a few seconds, when the whole apparatus spun around like any top, and mounted into the air faster than a bird; to what height it ascended I had no means of ascertaining; The distance travelled was across two fields, where, after a long search, I found the machine minus its wings, which had been torn off in contact with the ground."*

Reports of this flight vary as regards size and distance flown, but if authenticated would be the first recorded powered flight, some six years before Stringfellow (1848); it would also be the first recorded use of tip-jet drive, and the first successful steam driven helicopter model. It is believed that a replica of the model was placed on show at the exhibition held in 1868 by the Aeronautical Society of Great Britain (later to become the Royal Aeronautical Society).

1.2 Sir George Cayley (1843)

Sir George Cayley was typical of his times, a gentleman scientist of independent means, who showed a remarkably clear vision regarding the nature of flight and his work is considered to have played a significant part in the progress of "Aerial Navigation". As early as 1792, while still a student, he experimented with helicopter toys and concluded:

> *"This was the best apparatus for ascent but not for speed".*

Most of his work was concerned with the main preoccupation of achieving controlled flight. He eventually succeeded in getting his coachman airborne in one of his gliders in 1853. In April 1843, "Mechanics Magazine" published a description of "Sir George Cayley's Aerial Carriage". Powered by a steam engine, the machine employed two contra-rotating rotors arranged side by side to produce lift and it had two large propellers for forward flight. It is interesting to note that the design included a horizontal stabiliser for pitch control and a rudder for yaw. Even more remarkable was the fact that the rotor blades included variable pitch, whereby they could be closed to form

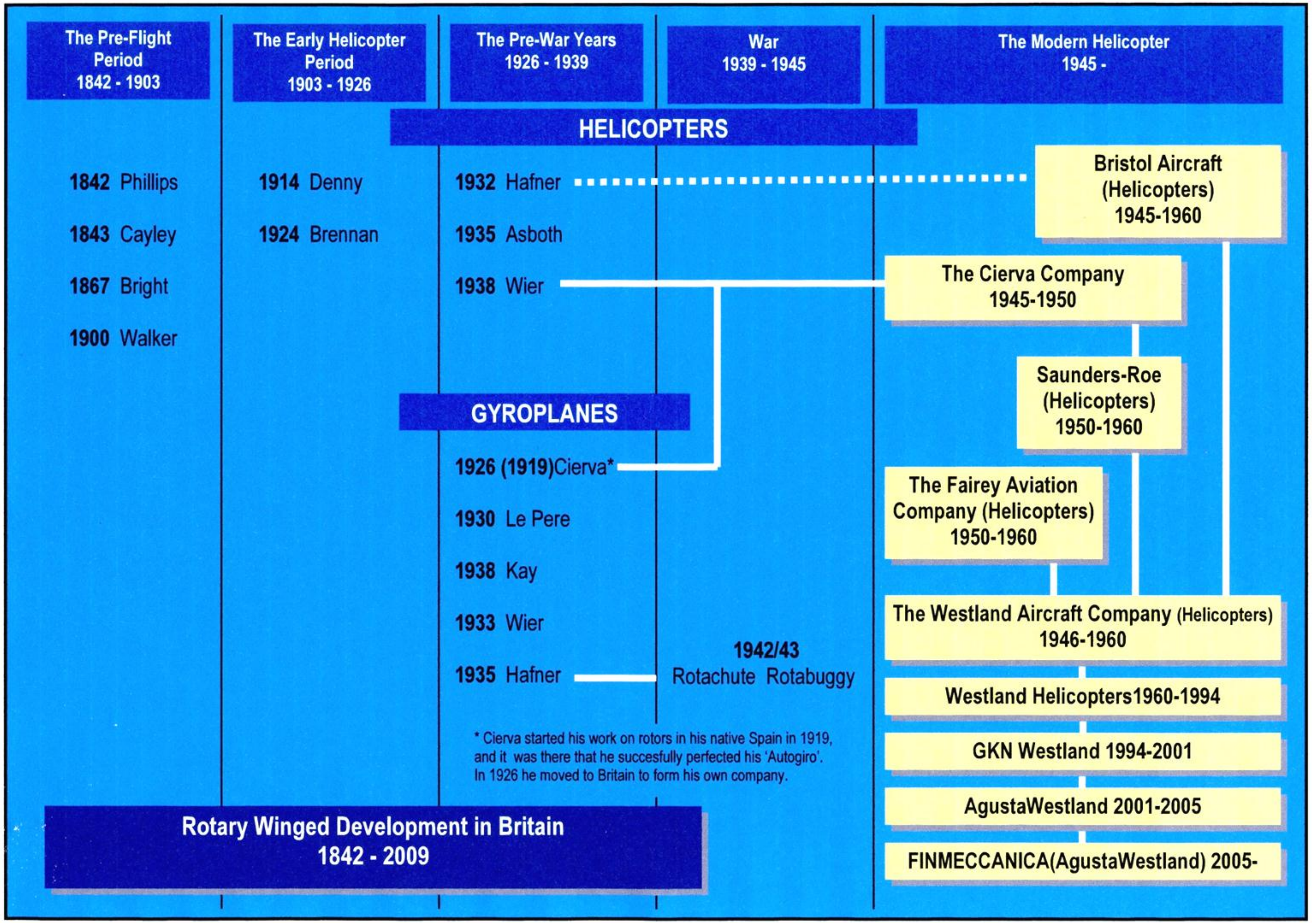
The Pre-Flight Period 1842 - 1903
The Early Helicopter Period 1903 - 1926
The Pre-War Years 1926 - 1939
War 1939 - 1945
The Modern Helicopter 1945 -
HELICOPTERS
1842 Phillips
1843 Cayley
1867 Bright
1900 Walker
1914 Denny
1924 Brennan
1932 Hafner
1935 Asboth
1938 Wier
Bristol Aircraft (Helicopters) 1945-1960
The Cierva Company 1945-1950
Saunders-Roe (Helicopters) 1950-1960
The Fairey Aviation Company (Helicopters) 1950-1960
The Westland Aircraft Company (Helicopters) 1946-1960
Westland Helicopters1960-1994
GKN Westland 1994-2001
AgustaWestland 2001-2005
FINMECCANICA(AgustaWestland) 2005-
GYROPLANES
1926 (1919)Cierva*
1930 Le Pere
1938 Kay
1933 Wier
1935 Hafner
1942/43
Rotachute Rotabuggy
* Cierva started his work on rotors in his native Spain in 1919, and it was there that he succesfully perfected his 'Autogiro'. In 1926 he moved to Britain to form his own company.
Rotary Winged Development in Britain 1842 - 2009

Figure 1

circular wings once forward flight had been achieved. In modern terms it would be described as a Compound Helicopter or Convertiplane.

In Cayley's own words:

> *"The Aerial Carriage would be capable of landing at any place and remaining stationary, or nearly so, in the air".*

Like many pioneering efforts, Cayley's ideas were too far in advance of the available power units or structural materials.

1.3 Henry Bright (1859)

In 1859, Henry Bright patented a device which incorporated contra-rotating rotors to counteract torque, intended to control the ascent and descent of balloons. This was the first British patent to be granted for rotary wing design, and as such this was a significant event. It was a demonstration that someone had confidence in the use of rotors, and foresaw that at some time in the future, applications would be found which could be commercially exploited.

1.4 Sir Charles Parsons (1895)

In 1895, Sir Charles Parsons, who is accredited with the invention of the marine steam turbine, built a model in which a single rotor was driven by a steam engine developing ¼ hp at 1200 rpm.

1.5 W. G. Walker (1900)

During the period 1900 to 1905, W. G. Walker conducted a series of experiments to determine rotor lift. The experiments involved measurements of vertical lift generated by a series of propellers of 30 ft (9.1 m) diameter. Five different propellers were tested at ten speeds, between 20 and 60 rpm, at a range of blade incidence angles between 12 and 21 degrees. The results were published as tables and are significant in that they represented a precise scientific approach.

2. THE EARLY HELICOPTER PERIOD (1907 - 1928)

The flight by the Wright Brothers in December 1903 was, as might be expected, a defining moment. Others quickly followed their success and an understanding of the problems of control, stability, lightweight structures and power requirements rapidly developed. Most of the activity centred around the fixed-wing aeroplane but from 1907, attempts were made both in Europe and the USA to achieve flight with rudimentary helicopters. Some limited success was achieved, and so progress was made.

2.1 Denny (1914)

Commencing in 1905, the Denny Company designed and built a large helicopter. The six rotors were mounted in side-by-side pairs and had the appearance of large 25 ft (7.6 m) diameter ships propellers, each rotor of a pair intermeshing with the other. The machine was powered by a 40 hp petrol engine and control was achieved by tilting the rotor shafts using cables. Initially the basic airframe was made of bamboo but this was subsequently replaced by a metal structure.

After several modifications, a short tethered hover was accomplished at a height of 10 ft (3 m). It was later fitted with floats and a successful flight was achieved in 1914, when it flew a distance of 300 ft (91 m) at a height of 10 ft reaching a speed of 15 mph (25 km/h).

Work was eventually discontinued after it had been wrecked in a gale, but also because the outbreak of the 1914-1918 war gave the Denny Company other more pressing needs for their engineering capabilities.

2.2 Brennan (1924)

Louis Brennan was an Australian by birth who established his reputation as an armaments engineer, with considerable success in torpedo design and a gyro stabilised monorail with military applications. As early as 1915 he had approached the War Office with proposals to produce a helicopter, and to this end a Secret Patent was taken out in his name. But it was 1919 before any work commenced on the helicopter project when the Air Ministry established Brennan at Farnborough, with all the facilities of the RAE placed at his disposal.

The Brennan helicopter (Figure 2) was based around a rotary frame carrying two blades driven by four bladed propellers at the blade tips. Power was provided by a single, horizontally mounted Bentley BR 2 rotary engine of 230 hp driving the two propellers through a gearbox via shafts running the length of the blades. The rotor diameter was 61 ft (18.5 m) and the blades had a chord of 6 ft (1.8 m). The structure rotated at 50/60 rpm and the all-up weight was 2,764 lb (1,256 kg). Brennan also designed an engine starting system for the aircraft.

It has to be appreciated that there were no helicopter pilots let alone test pilots, so the role was undertaken by Ronald Graham, Brennan’s assistant, himself an engineer who in later years went on to a distinguished career with the RAE.

The first flight took place in May 1924; subsequent flights consisted of brief hovers and limited transitions into low speed forward flight. In the course of the two years that followed, over 70 flights averaging three minutes were carried out, and significant progress had been made to achieve stability and control.

The project was discontinued in 1926 upon the recommendation of the Air Ministry Aeronautical Research Committee, who saw no future in helicopters of the Brennan type and advised that future rotary wing activities should be concentrated upon gyroplanes such as Cierva's 'Autogiro', which by this time was demonstrating spectacular success. Brennan tried in vain to get the decision reversed. In his letter to the Air Ministry he said:

"That the helicopter must and will come, I am now more convinced than when I started and it is irresponsible for anyone to impede it.”

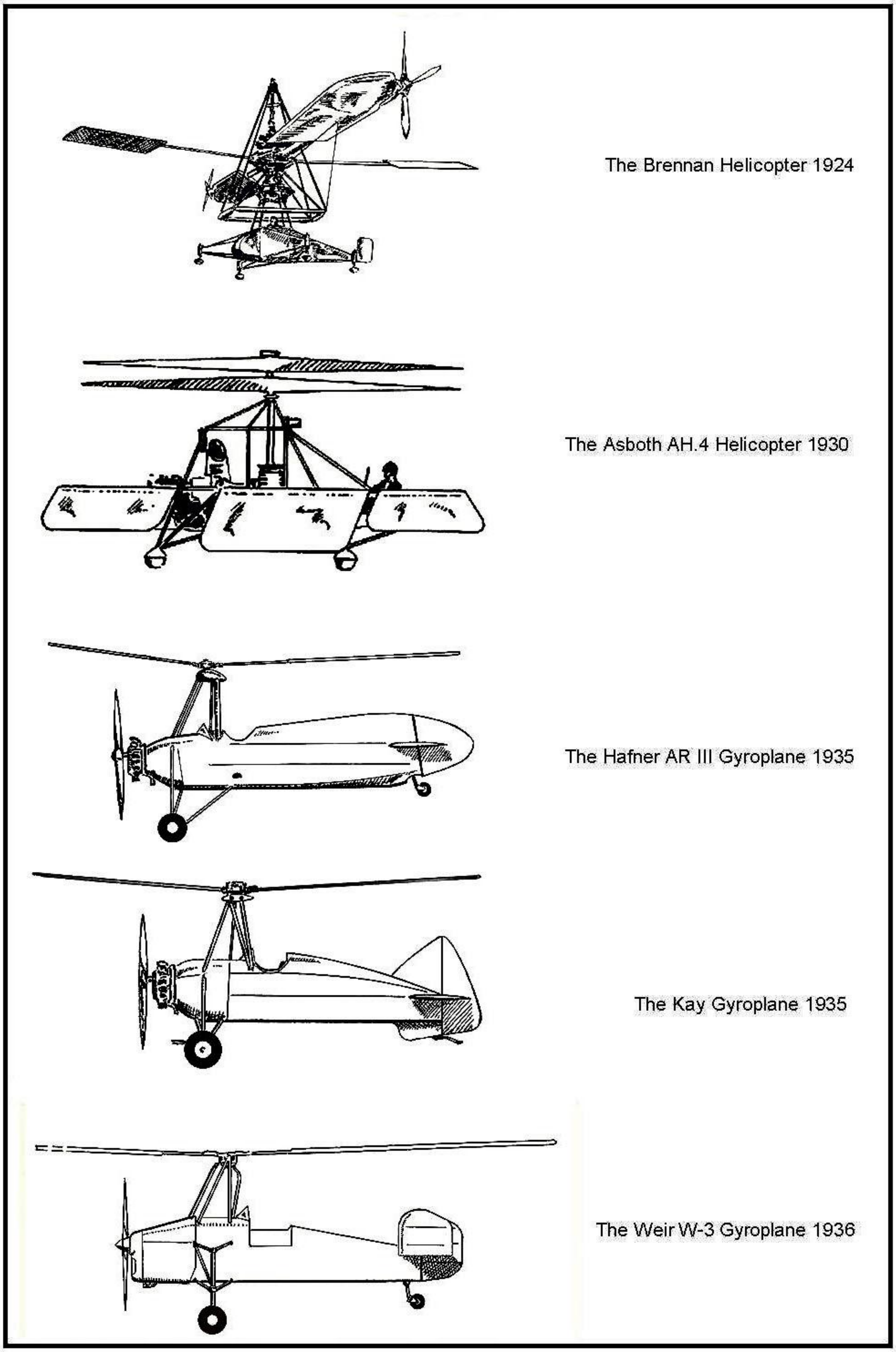

Figure 2 Early British rotorcraft 1924 - 1936

3. THE PRE-WAR YEARS (1926 - 1939)

The appearance of the first successful gyroplanes opened a whole new era in rotorcraft development; leading to an understanding of rotors and rotor mechanisms, which without doubt provided the key to the successful helicopter. A great deal of the gyroplane development took place in Britain, led in many significant cases by European engineers, giving some foundation to the premise that it is misleading to lay wholly national claims to scientific progress, as the following narrative will show.

3.1 Juan de la Cierva (1926)

The work of Juan de la Cierva is well documented and his pioneering work, which led to the development of his ‘Autogiro’, provided the basis of an understanding of rotors, which in turn led to the first practical helicopters (Figure 3). All Cierva's pioneering work was carried out in his native Spain but in October 1925 he brought his **C.6** to England and demonstrated it at the RAE Farnborough. This machine had a four bladed rotor with flapping hinges but relied upon conventional aircraft controls for pitch, roll and yaw. It was based upon an Avro 504K fuselage; initial rotation of the rotor was achieved by the manual tension of a rope passed around stops on the undersides of the blades.

The Farnborough demonstrations were witnessed by the Scottish industrialist James G Weir, who was sufficiently impressed with what he had witnessed to start negotiations which were to lead to the formation of The Cierva Autogiro Company Ltd in March 1926. The Weir support and influence in the Cierva Company continued until it was acquired by Saunders-Roe in 1951. The works was established at Hamble on Southampton Water, and from the outset Cierva concentrated upon the design and manufacture of rotor systems, relying on other established aircraft manufacturers to produced the airframes, predominately the A. V .Roe Company.

The Air Ministry quickly acquired three autogiros, a **C.6., C.8L** and a **C.9.,** with which an extensive experimental programme was carried out at the RAE.

The Avro built **C.8**. was basically a refinement of the C.6., with the more powerful 180hp Lynx radial engine, and several C.8s were built. The **C.8R** incorporated drag hinges, as it was found that the flapping hinges caused blade oscillation in azimuth, giving rise to high stresses with the risk of blade failure. As with all development, this brought on other problems such as ground resonance, for which friction-type drag dampers were fitted. The resolution of these fundamental rotor problems opened the way to progress. Confidence built up rapidly and after several impressive cross country flights a C.8L was entered for the 1928 King Cup Air Race and although it was forced to retire, it subsequently completed a 3000 miles (4800 km) tour of the British Isles. Later that year it flew from London to Paris, extending the tour to include Berlin, Brussels and Amsterdam, thus becoming the first rotating wing aircraft to cross the English Channel.

A predominant problem with the gyroplane was concerned with achieving initial rotor rotation. In addition to the rope and drum system, several methods were attempted which could take the rotor speed to 50% of that required at which point movement along the ground to reach flying speed

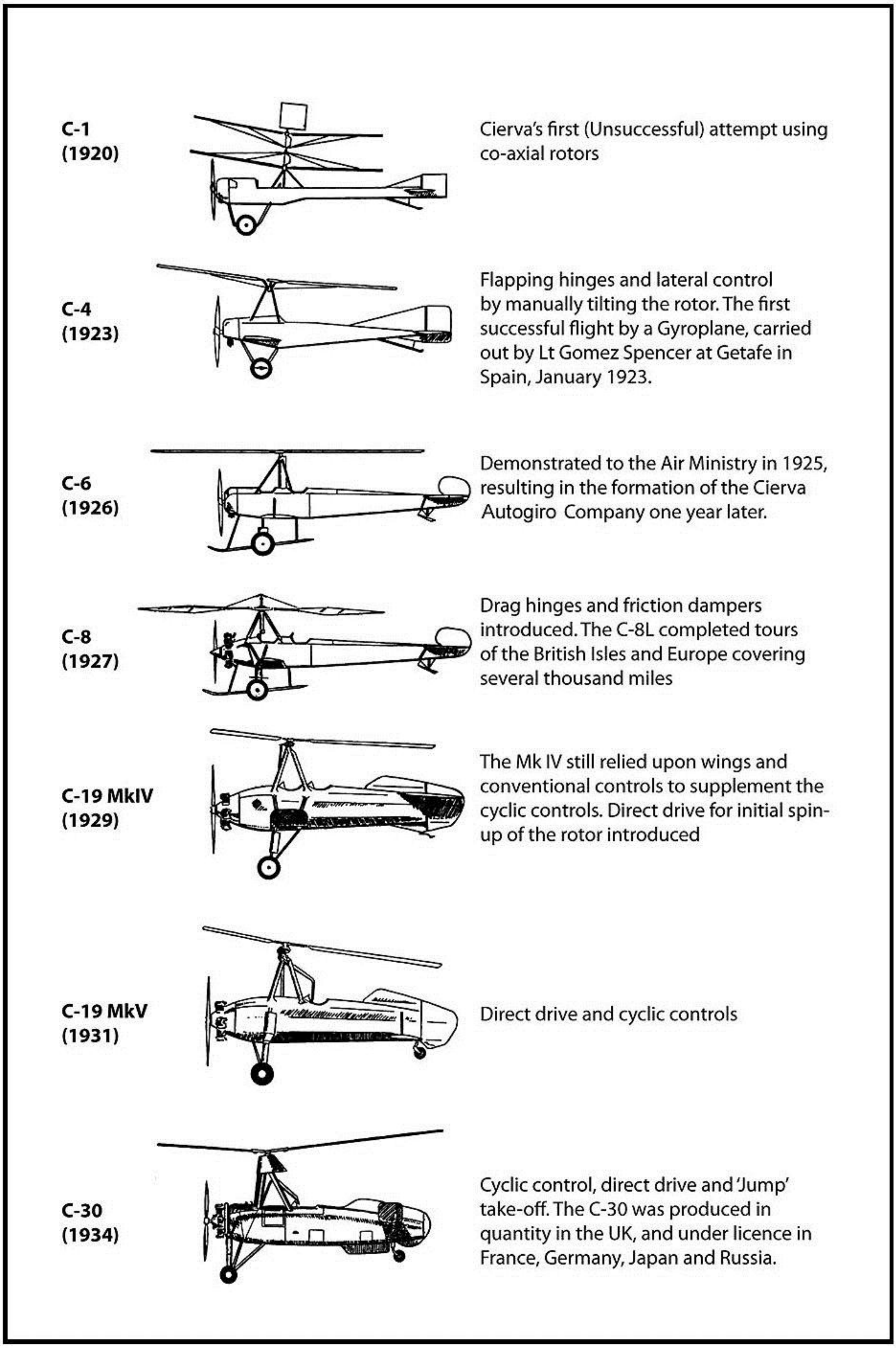

Figure 3 The development of Cierva's Autogiros 1920 - 1936

was necessary, while tilting the rotor to establish autorotation. Another approach was to tilt the tail stabiliser to deflect engine slipstream up through the rotor. The acceptable solution was finally achieved with the **C.19.,** which was produced in some quantities. A direct drive from the engine to the rotor was fitted, through which the rotor could be accelerated up to speed; the system was then declutched for the commencement of the take-off run.

As Cierva's autogiros achieved success and acceptance, others began to follow and with them came further innovation. Most important was the development of direct rotor control, which was achieved by the application of cyclic pitch, causing the blades to rise or fall at appropriate points in their rotation, thereby effectively tilting the rotor in the required direction.

The introduction of jump take-off was another major improvement in capability. The rotor was accelerated in fine pitch until the rotor speed required for flight was achieved and was then declutched. The loss of torque caused the blades to swing forward on angled drag hinges with a resultant increase in collective pitch, causing the aircraft to leap into the air in a spectacular fashion. With all the engine power now applied to the forward thrusting propeller, it was then possible to continue in forward flight with the rotor in autorotation.

All the above features were brought together in the **C.30,** which was produced in quantity for civil and military use. The autogiros of the 1930s were looked upon as a wonder of their time. It must however be emphasised that they were not helicopters, and were not capable of vertical take-off, landing or hover in still air, albeit that they could maintain very low speeds and accomplish a near vertical landing into wind.

The activities of the Cierva Company established a strong understanding of rotorcraft throughout the world. Within the British aircraft industry, a number of manufacturers produced aircraft for Cierva including Avro, Comper, De Havilland and Westland. The Company was strongly associated with the Scottish Weir Engineering Company, which provided a lot of financial backing for Cierva and was actively involved in the design of gyroplanes and later helicopters.

Juan de la Cierva died in an airliner crash in 1936. It is interesting to note that although his work led the way to the helicopter, he himself never set out to create such a machine. His aim was to produce an aircraft which was safe from the stall.

Cierva 'Autogiro' designations

C6C Clerget 130 hp engine - Four rectangular blades - Fixed head - Flapping hinges - Rotor diameter 36 ft (11 m) - Single seater. Built around an Avro 504K fuselage.

C6D As C6C, except that it was a two seater, and had stub wings aimed at unloading the rotor. During trials a blade broke. This was attributed to rigidity of the blades in the plane of rotation.

C8R Rebuilt version of C6D with larger diameter rotor, four paddle shaped blades with flapping and drag hinges. Two-seater, with a rotor diameter 39ft 7ins (12.1 m).

C8V Same as C8R, but with a Viper engine.

C8L Built around Avro 504N fuselage, with four-bladed rotor, dual control, and stub wings. Engine: Armstrong-Siddeley Lynx, 180 hp.

C8L (Mk.ll) Rotor free around axis, but its four blades were jointed by cables to prevent excessive motion in the plane of rotation. The fixed wing had conventional ailerons. In 1928 made first cross channel flight.

C9 Small single seater. Rotor diameter: 30 ft (9.1 m). Engine: Genet 1, 70 hp.

C10 Single seater, fixed head, stub wings, rudder and elevator. Engine: Genet I, 70 hp. Crashed on first flight.

C11 Engine: Airdisco, 120 hp. An attempt to get satisfactory rotor without drag hinges. Crashed on first take-off run and never rebuilt.

C12 First with floats.

C17 First built with Cirrus 85 hp engine but proved to be underpowered. Rebuilt with an Avro Alpha Engine of 100 hp. Four-bladed rotor. The aircraft was later converted to C19 Mk.IV.

C19 (Mks I, II & III) These models, the first of the C19 series, had a new fuselage designed by Cierva. In these early models of the C19, the rotor was started not by a crew pulling on a rope wound round the hub, but by means of a deflector tail. All three were two-seaters, and had four-bladed rotors of 30 ft (9.1 m) diameter. Engine of Mk.1: Genet 70 hp; other marks: Genet 100 hp.

C19 (Mk.IV & V) Both these models had an improved method of starting the rotors by connecting a light clutch to the engine drive. Engine: Genet Major 1, 100 hp. Three-bladed rotor, diameter 35 ft (10.7 m). In Mk. V there were no stub wings. This was used by Cierva to study the behaviour of a "direct control" capable of tilt in all directions. This gave not only lateral, but fore and aft control.

CL20 Designed by Le Pere and constructed by Westland at Yeovil. Direct control head. Three untapered blades on flapping and drag hinges. Engine: Pobjoy 90 hp.

C24 A two seater, cabin aircraft, for which De-Havilland were responsible for the basic design and construction, based on an extensively modified DH-80A Puss Moth fuselage. It had a three blade rotor of 34 ft (10.4 m) diameter and a tricycle undercarriage.

C25 This small single seater had an 85 hp Pobjoy Engine, a three-bladed rotor with flapping and drag hinges, and mechanical drive starting. The aircraft was built by Comper, around a Comper Swift fuselage. Tests were proceeding when a blade broke and the design was abandoned.

C29 An experimental 5-seater, designed and constructed by Westland. Engine: Jaguar 400 hp.

The rotor head was of the "direct control" type and extensive use was made of duralumin tubing in the construction. The prototype never flew due to ground resonance. Before this could be rectified Cierva died and work was abandoned.

C30 Could be considered to be the definitive Cierva 'Autogiro'. The early model had 100 hp Genet but the production model had the bigger 140 hp Genet, and a 3-bladed "direct control" rotor head with mechanical drive starting gear. More than seventy C30s were built and flown by Avro, including ten for the Royal Air Force.

C40 In 1936, trials began on a C30 embodying an "auto-dynamic" head to ensure direct take-off. With the blades set at a non-lifting angle, the rotor was speeded up by the engine, and as soon as sufficient kinetic energy had been stored, the blade pitch was increased so that the autogiro could leave the ground vertically in a "jump take off". Development was halted by the war but experimental models were demonstrated.

3.2 Isacco (1928)

Isacco, who had worked in Spain with Pescara, had built a "Helicogyre" in Paris. He never postulated that such a type should be able to lift without forward speed, and as a result he fitted a forward engine. His prototype was a two-bladed single seater, with Anzani engines of some 30 hp, mounted at the tips of the blades. This was the first aircraft, which Liptrot (Aeronautical Research Council) flew in 1928.

The British built Isacco Type:

In 1928 the British Air Ministry ordered a third prototype, this time using a four-bladed rotor, with Cherub engines at the tips of each blade. Each blade was virtually a complete small aeroplane, freely hinged but constrained to move in a circular path, and provided with a complete set of aerodynamic controls. The forward engine was an Armstrong-Siddeley Genet of 100 hp. As distinct from Isacco's original idea it was considered necessary to provide definite lateral control. This was achieved by adding a supplementary control rotor carrying two planes rigidly attached to the control post, differentially operated during each revolution to equalise lift, whose incidence was controlled from the pilot's column. Trouble was experienced at first due to the carburetion distribution and oiling systems operating in an intense centrifugal field. These were made worse in the actual aircraft since the only engines available were horizontally opposed twins so that the outer cylinder got too much oil. However, by close attention to piston clearance and fitting a centrifugally controlled orifice to meter the fuel, the engines ran satisfactorily, at any rate for short periods. Liptrot carried out initial tethered trials but it was ruled that Isacco must carry out free tests himself. An accident to his own aircraft prevented this, and as he could not fly the British Type, the development came to an end.

The first British aircraft was built by Saunders at Cowes.

Engines: 4 Cherub on wings, 4 x 32 hp.
Seats: 2
Rotor Diameter: 48 ft 2 in (14.7 m).
Weight: 2,920 lb (1,326 kg).

3.3 Asboth (1928 - 1935)

Most of Oscar de Asboth's activities took place in his native Hungary where he produced four helicopters, which are outside the context of this discussion. His AH.4 (Fig 1) had twin contra-rotating fixed pitch wooden rotors and achieved control by means of six surfaces hanging on horizontal hinges, which could be inserted to deflect the downdraught as required by the pilot.

In 1930, a British delegation went to Budapest, and the AH.4 was flown by Capt R.N.Liptrot to a height of l00ft and covered a distance of 1.67 miles (2.7km). The result of this event was that in 1935, Asboth signed an agreement with the Air Ministry to design a new type, the AH.5, based upon his concepts. The design was completed and it was to have been constructed by the Blackburn Aircraft Company, but this was prevented by the approach of war and Asboth returned to Berlin.

3.4 Kay Gyroplane (1935)

Towards the end of 1934 Oddie, Bradbury and Cull Ltd. built a gyroplane (Figure 2) to the specifications of David Kay. In Kay's single seat, direct control gyroplane, the four bladed rotor was mounted on a pylon. Positive control of pitch was obtained by varying the incidence of the blades (collective pitch). Longitudinal control was by a hinged tail plane and elevator, and lateral control was achieved by tilting the rotor head. The engine was a Pobjoy 75 hp. and the rotor diameter was 22 ft (6.7 m).

3.5 Raoul Hafner (1932 - 1939)

Raoul Hafner had achieved some success working with Bruno Nagler in his native Austria (see also section 3.6). He moved to Britain in 1932 with his R-2 helicopter, on which the 3-blade rotor had collective and cyclic pitch control achieved through a swashplate, and the torque reaction was controlled by two large moveable vanes placed in the downwash. A number of short flights were achieved but control was difficult and was never fully refined.

Hafner expanded his activities in the UK by the formation of a company, The A.R.III Construction (Hafner Gyroplane) Company, with the intention of building his **A.R.III Gyroplane**. The A.R.III was a small single seat gyroplane, powered by a Pobjoy engine of 84 hp, incorporating all the features of the Cierva machines, such as cyclic pitch control for the rotor. It also included collective pitch on the main rotor blades and tie rods incorporated in the rotor blade attachments, which reduced friction in the highly loaded pitch change bearings.

The control of the AR.III included a collective control lever in addition to the cyclic control, resulting in an arrangement similar to that now common in most helicopters, and the result gave handling qualities which were in advance of anything previously achieved. Although the A.R.III was essentially a gyroplane, it was Hafner's declared intention to use it as a proving tool for an improved helicopter.

Following the success of the AR.III, Hafner began work on the **A.R.IV** and **A.R.V**, which were to be two and three-seaters respectively and boasted enclosed cabins. But also design work was initiated on two helicopters, the **PD.6** and **PD.7**, in which torque would be balanced by means of vertical fins in the rotor downwash. Like many of the projects which were nearing fruition in the late 1930's, Hafner's adventurous intentions were curtailed by the approach of war.

3.6 Bruno Nagler (1929 - 1937)

In 1929 Bruno Nagler worked in collaboration with Raoul Hafner to produce the R-2 described above.

In 1936, he produced his **Helicogyro** and carried out trials in 1936/37. This had a two bladed rotor of the same diameter as the R-2, with a Pobjoy engine of 90 h.p. driving a pusher airscrew. Both anti-torque and directional control were obtained by putting a rudder in the slipstream from the pusher airscrew. The blade construction was of interest, consisting of seamless steel tubes which were nested together to build up the profile, and were electrically welded along the vertical flat sides to form a multi-web stressed skin blade. The inventor was unable to get a variable pitch airscrew suitable for the Pobjoy engine and for demonstration purposes a fine pitch screw was used for hovering and changed over to a coarse pitch screw for translational flight. Hovering was accomplished in very bad weather. Anti-torque control was demonstrated to be adequate and indeed sufficient to turn the aircraft against torque. A simple type of cyclic pitch control was incorporated.

3.7 Weir Gyroplanes (1933 - 1936)

The Scottish Engineering Company of G & J Weir played an important part in the formative years of rotorcraft development in Britain. The Weir family provided much of the finance and encouragement to get Cierva started, and the Weir Company then proceeded to undertake the design and construction of an attractive range of small gyroplanes, based on Cierva designs and aimed at production for the civil market.

W1 This was a single-seater with a fuselage designed by C. G. Pullin with a two-bladed rotor, the blades of which had flapping and drag hinges, while the head was of direct control type. A mechanical drive starter was used to give initial motion to the rotor. The engine was a Douglas Dryad of 40 hp, and the rotor diameter was 28 ft (8.5 m).

W2 This bore a close resemblance to its predecessor except for a more powerful engine, which was a Weir 50 hp flat twin. The rotor diameter was 28 ft (8.5 m).

W3 (Figure 2) This was also a single-seater fitted with a two bladed 'Autodynamic rotor', which could make a "jump take-off".

W4 This was an improved version of the W3, all features of the W3 being retained.

The Weir gyroplanes were attractive in appearance with small economic power units and they were clearly aimed at a mass market with the intention of quantity production. Their design and development brought together a team of specialist engineers who went on to provide a strong technological base for future rotorcraft projects, and many of the Weir team remained active in the industry long after Weir had ceased its aircraft activities.

Weir Helicopters (1937 - 1940)

The Weir Helicopters followed on directly from their gyroplane work. The key figure in this activity was their Chief Designer, C. G. Pullen.

The chosen configuration was to use two rotors mounted side-by-side. Control was achieved by means of cyclic pitch, allowing movement in all axes augmented by conventional rudder and elevator. There was no collective pitch control so that power for take-off and landings was controlled by using the throttle. The absence of pitch control meant that autorotation was not an option!

The single seat **W5** flew for the first time in 1938 and, excluding Brennan's limited success, can lay claim to be the first British helicopter to achieve controlled flight. The power unit was a 50 hp Weir Pixie, driving two small l5ft diameter rotors; the all-up weight was 840lb (380kg).

The second Weir helicopter, the **W6** (Fig 3), was much larger; a two-seater with a fan cooled 205 hp de Havilland Gypsy Queen Six engine, driving two three-bladed rotors of 25ft (7.6 m) diameter. The control system was basically similar to the W5, lift being controlled by changing the rotor speed. The collective pitch setting for autorotation in the event of engine failure was activated by the loss of engine oil pressure.

A considerable amount of success was achieved with the W6, which being a two-seater allowed a number of influential engineers and officials to experience helicopter flight as passengers. However helicopter work at Weir was discontinued in 1940 due to war priorities.

3.8 Comment

By 1939 the state of the art regarding the development of the helicopter was well advanced. Viable helicopters were flying in Europe and the USA.

In **France**, the Breguet-Dorand helicopter was demonstrating a high level of controllability, including an autorotative landing, and achieved 62mph (99.7kph).

In **Germany**, the demonstration of the Focke-Wulf Fw-61 in the Deutchlandhalle in 1938 and its subsequent achievements of speed and range were convincing evidence of progress. Flettner had flown his Fl 185 and 285 leading to production during WW-2

In **USA**, Hiller, Piasecki, Sikorsky and Young were all developing helicopters that would result in production aircraft.

The age of the helicopter was nigh!

4. THE WAR YEARS (1939 – 1945)

The outbreak of war with Germany had an inhibiting effect upon all work on rotorcraft in Britain, where certainly during the early years every available resource was required to maintain the demands of conventional air power. The Weir helicopter was beginning to show promise and refinements of the W6 were under consideration in mid 1940, when the team was disbanded to work on projects which were considered to be of greater importance to the war effort. The Cierva Autogiros, of which there were a number available, mostly C30s and C40s, were formed into a specialised unit to assist in the calibration of the newly invented radar, which in turn was a major factor in the "Battle of Britain". Their unique low speed capability made them ideal for this function and the unit continued to operate under various titles throughout the war, accumulating over 9,000 flying hours.

4.1 Rotachute & Rotabuggy Projects (1941 - 1944)

Early in the war, Raoul Hafner made some proposals to develop a light autorotating system for use with airborne forces. The craft, which was intended to be very light, would be carried in a folded state in an aircraft and would open automatically upon release. The controllability offered by such a system promised considerable advantage over the parachute and would enable key groups such as artillery spotters and machine-gun groups to be positioned safely and accurately, with their equipment.

Named the **Rotachute** (Figure 4), it had a two bladed rotor of 15 ft diameter with an empty weight of 48 lb (21.8 kg). A special unit was formed at Ringway near Manchester to undertake development as part of the Central Landing Establishment, concerned with airborne warfare. During tests, the Rotachute was towed behind an aircraft to altitudes up to 4000ft and then released to glide (autorotate) back to the ground. Twenty Rotachutes were built but it was never used operationally.

As a follow-on to the Rotachute, work was started to develop a system to deliver a light vehicle in a similar fashion. This was the **Rotabuggy** (Figure 4). This was basically a "Jeep" of approximately 550 lb (250 kg) fitted with a detachable pylon-mounted rotor and a stabilising tail unit, which could be towed behind an aircraft for release as required. One was built and completed over 60 test flights but never proceeded beyond the initial test phase. Design studies were undertaken to consider the possibility of using the system to deliver a light tank.

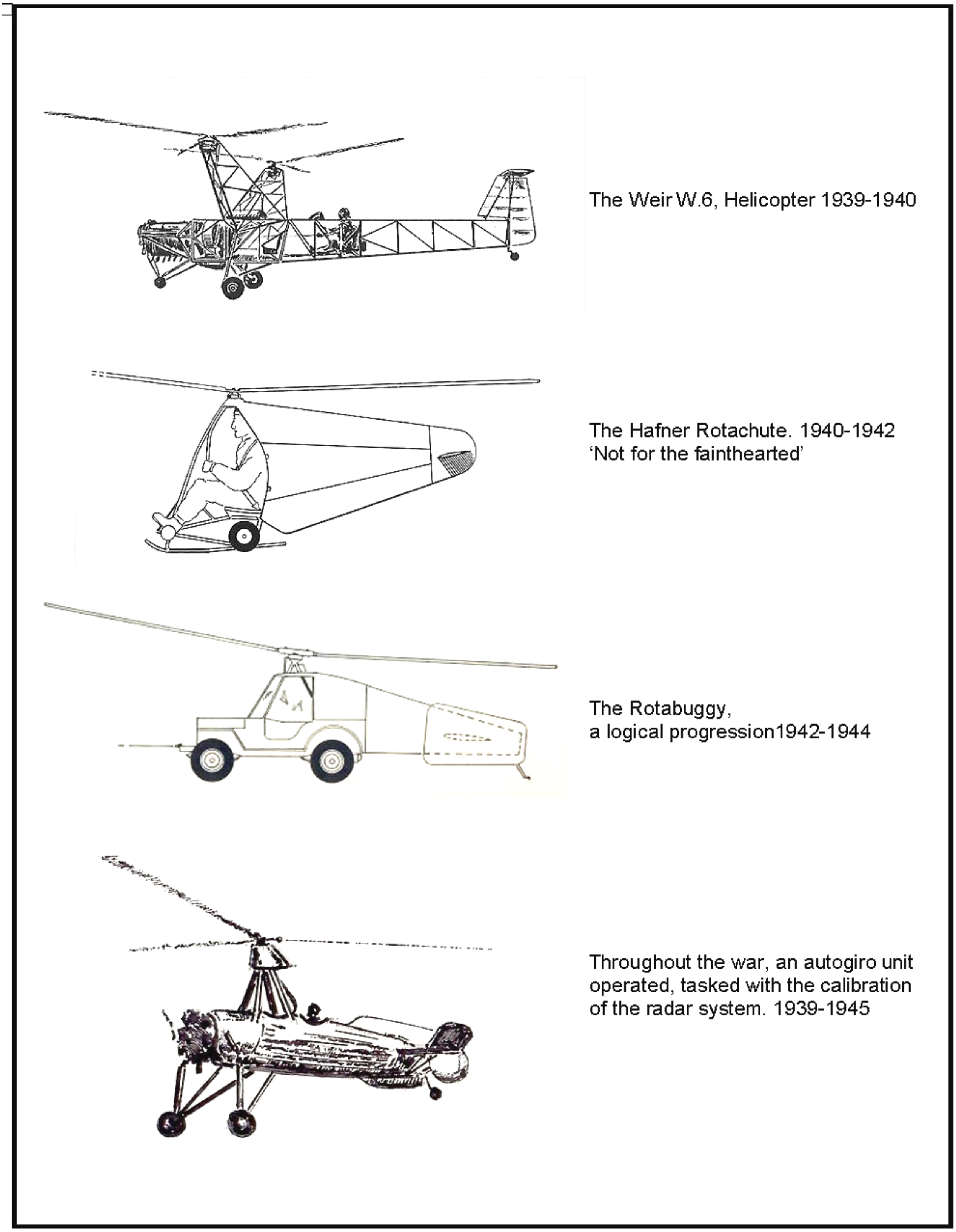

Figure 4 Rotorcraft activity in the UK during World War 2 was very limited 1939 - 1945

5. THE EMERGENCE OF THE HELICOPTER (1945 - 1960)

By the end of World War 2, viable helicopters had been produced by both opposing sides.

In the **USA** there were four helicopter projects that were clearly leading to quantity production with civil and military applications hitherto unknown for any flying machine, and it was clearly perceived that such aircraft had a place in the post-war world.

The question; 'Who invented the helicopter?' often gets raised, and is almost impossible to answer, but the work of the 'American big four' (Hiller, Piasecki, Sikorsky and Young) must rank as a defining moment

In wartime **Germany**, a number of helicopter projects were developed, put into production and service. The Focke-Achgelis Fa223 and Flettner 285 were deployed operationally, and 'Doblhoff' (Freidrich von Doblhoff) flew an experimental jet powered machine.

The unique capabilities of Rotorcraft were embraced with enthusiasm, to form a new industry.

Within a year following the end of hostilities, four major British aircraft manufacturers had formed helicopter design and development teams, intent upon putting the helicopter into its rightful place as a versatile transport with the unique capability to take off vertically and hover, while fitting in with other forms of air transport.

5.1 The Bristol Aeroplane Company (Helicopters 1946 - 1960)

As early as November 1944, Raoul Hafner was invited to join the Bristol Aeroplane Company to head a team devoted to rotorcraft design. He brought with him project studies for a four-seat helicopter which resulted in the **Bristol Type 171 Sycamore**, in response to a Ministry Specification. The first flight took place in July 1947 and by April 1949 it had gained the first full Certificate of Airworthiness to be awarded to a British helicopter. A total of 180 Sycamores were built, more than half of which served with the Royal Air Force. The Sycamore introduced helicopters to the RAF and was used to develop Search and Rescue and also rudimentary Tactical Support.

The next project undertaken by the Bristol team was the **Bristol Type 173**. This was a much more ambitious proposition, the result of which flew for the first time in January 1952. The Type 173 was a large tandem rotor helicopter of 11,000 lb (5,500 kg) all-up weight with twin engines; it was aimed at the civil transport market with the capability of carrying thirteen passengers. It was evaluated by British European Airways, but never entered airline service. The development programme included tests with stub wings to off-load the rotors, aimed at achieving higher cruising speeds; one of the five Type 173 prototypes flew in this configuration.

The **Type 192**, later to become the **Belvedere** (Figure 5a), was derived directly from the Type 173 to fulfil the requirement for a large transport helicopter for the Royal Air Force. Although it was physically similar to the Type 173, it differed in that it was powered by two 1,300 hp Napier Gazelle turbines, and could operate at an all-up weight of 19,000 lb (8,600 kg) with the capability to carry 18 fully armed troops. The prototype flew for the first time in July 1958 and the Belvedere entered RAF service in September 1961, serving with the RAF until March 1969. A total of 26 Belvederes were built.

In March 1960, the helicopter interests of the Bristol Company were taken over by Westland. At the time a number of project studies were under consideration including a four engine tandem rotor transport which included stub wings to off-load the rotors, designed to cruise at 173 kt (320 km/h). There were also plans in place for a large tilt-rotor VTOL aircraft of 60,000 lb (27,250 kg) all-up weight, designed to cruise at 347 kt (643 km/h).

5.2 The Cierva Autogiro Company (1945 - 1950)

The work of Cierva and Weir was very closely linked, and the Weir Company continued with a limited amount of project study work on Cierva's behalf throughout the war years. Once hostilities had ceased, the Cierva Autogiro Company was re-established, bringing with it, by agreement, many of the key personnel from Weir.

The first project undertaken was the **W.9**. This machine was unique in that it utilized air from a multi-bladed variable pitch ducted fan, driven from the main engine, to provide air to a controllable efflux situated at the rear of the fuselage, thrusting to port to counteract main rotor torque. The thrust available was controllable through the rudder pedals, thereby providing yaw control. The intention was to investigate an alternative to the tail rotor, which already had become established as the way ahead for most helicopters. The limited success achieved was not sufficient to offer a viable system, given the "state of the art" at the time.

The company moved to Southampton in 1946 and work started on the **W.11 Air Horse**. This was a large transport helicopter of 17,500 lb (7937 kg) capable of carrying 26 passengers, aimed at the civil and military markets. Power from a single 1620 hp Merlin engine was transmitted through shafting to three rotors, each having three blades, situated in a triangular plan form, one at the nose of the aircraft and two, side by side at the rear. The prototype flew for the first time in December 1948 and the programme was well advanced when the aircraft crashed following a main rotor failure. Although a second Air Horse had already flown the project never recovered from the disaster and work was discontinued.

Work started on the **W.14 Skeeter** in parallel with the Air Horse. The Skeeter was designed as an economic two-seat helicopter, intended for training and observation duties. The prototype made its maiden flight in October 1948 and there followed a protracted period of development to solve a number of issues including a serious ground resonance problem. The developed version of the Skeeter weighed 2,000 lb (907 kg) and was powered by a 180 hp Blackburn Cirrus Bombardier, in which form it went into production for the British Army as the Skeeter AOP Mk12. A total of 77 Skeeters were produced. The type was the first helicopter to be operated by the newly formed Army Air Corps and remained in service until 1966.

In late 1950, the Cierva Company sold its interests to Saunders-Roe, ending the Weir Company's connection with helicopters.

5.3 The Saunders-Roe Aircraft Company (1951 - 1960)

The Saunders-Roe Company was an established aircraft manufacturer with a long record of success manufacturing flying boats and seaplanes dating back to 1912. Their acquisition of Cierva was a new departure and they left the design team intact to continue the helicopter work and the production of the Skeeter. The operation of helicopters from small ships presented a number of unique problems for the designer and it was clear that Admiralty interest would not be attracted until solutions were evident. The Saunders-Roe team embarked upon the design of a five-seat light helicopter which it was hoped would have application for the Army and Navy, but would also find a place in the civil market.

The **Type P.531** was produced as a private venture. It utilized much of the Skeeter transmission, rotor head design and blades, with a Blackburn Turmo free turbine engine, downrated to produce 325 hp for a helicopter of 3,400 lb (1,540 kg). The prototype flew for the first time in July 1958 and the success was such that four improved prototypes (P.531-0) were ordered for evaluation by the services. There followed a period when an important range of experiments took place at RAE Bedford to determine the best landing gear arrangement for operation from small ships.

In the meantime work was in hand to install a more powerful engine, the Blackburn Nimbus rated at 625 hp, with a view to producing two similar but individually specialized aircraft for the Army and the Royal Navy. These were to become the **Scout** and **Wasp** (Figure 5a).

Saunders-Roe were acquired by Westland in August 1959 but the work carried out by the Saunders-Roe team was to influence small ship operations well into the future, and many of the key members of the group continued to work with Westland.

5.4 The Fairey Aviation Company (1945 - 1960)

The Fairey Aviation Company was one of Britain's oldest aircraft manufacturers, with a long record of successful aircraft going back to 1915. Following the end of World War 2, the management at Fairey perceived that the hour of the helicopter had come and that there was a clear application in the peacetime world for any aircraft capable of vertical take-off and with the ability to hover. A dedicated helicopter design team was formed under the leadership of Dr J. A. J. Bennett who had worked with Cierva and Weir; the group also included members of the German team who had worked with Freidrich von Doblhoff to produce his successful tip-jet drive helicopter in 1944.

Shortly before the outbreak of World War 2 Dr. J. A. J. Bennett, then with the Cierva Co., had put forward a design to Air Ministry Specification S22/38 for a ‘Gyrodyne’ combining the features of a helicopter and an autogiro, since it was to have an airscrew and one three-bladed rotor. In 1947 Bennett, then with Fairey, returned to the Gyrodyne idea and two prototypes were built.

Taking the name **Gyrodyne**, the new helicopter was to be a five seater. The fundamental idea exploited in the new aircraft was to use an offset tractor airscrew instead of the lateral thrust airscrew as a means of compensating torque reaction. In the Gyrodyne the power given to the

main rotor was kept as low as possible and the remainder utilised for forward propulsion. Stub wings and normal tail surfaces resulted in the Gyrodyne having a stable fuselage; the stub wings also served to off-load the rotor in forward flight. The other feature of interest was the rotor hub. Not only was the blade collective pitch set automatically by the throttle opening, but the pitch changing hinge was also eliminated. In the hub the drag hinge was given a small downward and outboard inclination, an arrangement that made the blade angle change as it was displaced about the hinge by changes in applied torque. As the throttle was opened, for instance, the blade lagged behind the direction of motion and increased its pitch angle, and vice-versa.
As there were no torsional bearings for pitch change, normal cyclic pitch could not be used. Instead of a separate swashplate to transmit control movements from the stick to each blade through levers, the rotor head virtually became the swashplate. The hub axis remained fixed, and it was only the rotor head, which was universally mounted on the hub axis, which tilted in respect to the axis.

Powered by an Alvis Leonides engine of 525 hp, the rotor diameter was 51.6 ft (9.65 m), and the all-up weight 4,800 lb (2,177 kg).

The Gyrodyne completed its maiden flight in December 1947. Initial testing proceeded well and in June 1948 the Gyrodyne gained a World Speed Record by flying a 3 km course at 107.94 kt (200.03 km/h). This success was overshadowed by the loss of the aircraft in a fatal accident ten months later, while working up for an attempt on the 100 km, closed circuit record. The accident was caused by fatigue failure in the rotor head and work on this promising helicopter was discontinued.

While the Gyrodyne work was in progress, the tip-jet group were working on the construction of a test rig facility at the flight test airfield at White Waltham and project studies were in hand responding to requirements for passenger carrying rotorcraft from British European Airways. Fairey were confident that a compound helicopter would be the answer and started work upon a demonstrator programme using the Gyrodyne. The second Gyrodyne was modified to accept tip-jets using kerosene mixed with air from two auxiliary compressors. Twin propellers were mounted on the stub wings to provide forward thrust and yaw control, and the rotor incorporated cyclic and collective pitch. The **Jet Gyrodyne**, as it was named, was capable of take-off, hover and transition as a helicopter. Once in level flight, the jets could be shut down and limited flight in an 'autogyro' regime was possible.

Although the Jet Gyrodyne could not maintain sustained level flight with the rotor in autorotation, and although the duration in this condition was short, it provided invaluable experience and data on the transition process, providing a convincing demonstration of the system's potential. By September 1956 the Jet Gyrodyne had completed 190 transitions and 140 autorotative landings. The success demonstrated with the Jet Gyrodyne provided sufficient confidence for Fairey to commit fully to tip-jet drive and start project studies on two major projects.

Work started on a small two-seat helicopter for use by the Army, and by the Royal Navy for small ship operation. The **Ultra-light Helicopter** was very small, with a loaded weight of only 1,800 lb (817 kg) and a rotor diameter of 28.4 ft (8.6 m) powered by a Turbomeca Palouste turbine. The rotor derived its power solely from tip-jets, using bleed air ducted to the tip to be burnt with kerosene. Control was of the conventional helicopter type with cyclic and collective pitch, and yaw was controlled through a stainless steel under-fin mounted in line with the main jet efflux. The little helicopter flew for the first time in August 1955, and the three prototypes completed a comprehensive test programme over a four year period, including trials at sea and civil certification before the project was finally abandoned in 1959 when the Ministry declared that larger helicopters would be required to fill the roles under consideration.

While the Ultra-light programme was in hand Fairey were working on an even more adventurous project. After extensive project studies a need for a vertical take-off airliner capable of carrying more than 40 passengers was identified. The **Rotodyne** (Fig 5) was designed to fill this requirement. It was large by any standards, with an all-up weight of 33,000 lb (14,979 kg) and an internal cabin length of 46 ft (14 m). The power was provided by two 2,800 hp Napier Eland propeller turbines, fitted with auxiliary compressors to power the tip-jets. The engines were mounted on a wing of 46 ft (14 m) span. The general arrangement was that of a compact medium sized turboprop airliner, with a tall rotor pylon to carry the 90ft (27.4m) diameter rotor with a pressure jet mounted at each tip.

The Rotodyne system worked as follows. For start up and take off and flight in the helicopter regime, the engine power was absorbed by the compressor providing air for the tip-jets, the rotor was run up on bleed air and once rotation was established, fuel was injected and ignition achieved. Once alight, burning was self sustaining and the pressure and fuel/air mixture were controlled with collective pitch application. Pitch and lateral control were maintained using cyclic pitch, and yaw was controlled by differential pitch of the propellers, augmented by the rudders once forward flight was achieved. Having achieved forward flight as a helicopter, collective pitch was reduced and the tip-jets shut down; power was then transferred to the propellers and the rotor established in autorotation. The aircraft was now flying as a gyroplane, and with the rotor off-loaded by the wings, it was capable of high speeds. Control was maintained by a combination of aerodynamic flying controls situated on the wing and tail surfaces, augmented by cyclic pitch. Transition back into the helicopter regime was basically a reversal of the process. A single engine capability was achieved by feeding diametrically opposite pair of blades from each engine.

Rotodyne made its first flight as a helicopter in November 1957 and made its first full transition as a convertiplane in April 1958. In the course of its four-year development programme, it completed over 155 flying hours, with over 400 transitions. Flights were made to Paris and Brussels, and landings were made in the heart of London. In January 1959, the Rotodyne captured a speed record over a 100 km closed circuit at 165 kt (307 km/h). Considerable worldwide interest was generated and plans were in hand for a larger production model weighing 53,000 lb (24,264 kg) capable of carrying 65 passengers. There were still many development problems, in particular that of noise, for which Fairey claimed that solutions were available. Civil and Military support was withdrawn by the British government in February 1962, overseas interest quickly evaporated and it became clear that the project could not proceed without further financial support and the promise of orders.

By the time the Rotodyne was cancelled, control of Fairey had been taken over by Westland. It is interesting to note that over the ten years during which Fairey had been a helicopter manufacturer, they only constructed six airframes, all impressively innovative, but none achieved production status.

5.5 Servotec (Rotorcraft Ltd) (1952 - 1964)

When Saunders-Roe took over the Cierva interests, J. Shapiro, the Chief Engineer of Cierva, set up a private company, **Servotec**, with the intention of producing a light two-seat, twin-engined helicopter. They produced the **Grasshopper**, powered by two 100 hp Walter Mikron engines driving contra-rotating rotors and weighing 2,880 lb (1,306 kg). A prototype was built to fly in March 1962 and the flight development programme continued on a very limited budget for approximately one year with some success.

Further finance was gained and the company re-structured as **Cierva Rotorcraft Ltd** to produce a four seat aircraft powered by two Rolls-Royce Continental engines, with the designation **Grasshopper 3**. The dynamic design was developed from the earlier Grasshopper with a completely redesigned airframe. Three prototypes were constructed, the first of which of flew in 1969. The intention was to offer the aircraft to be considered for the British Army as a Unit Light Helicopter, but this did not materialize and civil interest was limited. Testing was well advanced when the project was abandoned.

5.6 Hunting Percival (1950 - 1956)

Hunting Percival was a company with a record of successful light aircraft which had expanded its activities into the jet trainer market. It entered the helicopter field with a new concept based around the Napier Oryx gas producer system, relying totally on the low pressure, low temperature efflux mixed with air from an auxiliary compressor to provide relatively cold air to the tips. The demonstrator aircraft, the **P-74** was of conventional main and tail rotor layout, with a 55ft (16.75m) three-bladed rotor and all-up weight of 7,750 lb (3,515 kg). The rotor was of the tilting type, with non-feathering blades fitted with ailerons to obtain pitch variation. The aircraft was ready for ground run early in 1956. However, ground running showed that the desired performance was not achievable without extensive re-design and the project never proceeded beyond this stage.

5.7 Firth Helicopters (1951 – 1952)

Firth Helicopters existed only for a brief period, to design and build a light two-seat twin-rotor helicopter. This was built around the "Planet Satellite" light aircraft (circa 1948) and was based on Landgraf patents. It had a pair of rigid rotors, each with 3 blades, and cyclic pitch control from ailerons at the tips. The rigid rotors eliminated all oscillating bearings but were to have sufficient strength to withstand the periodic forces. The detail design was by Heenan & Froude but there was poor weight control so that while the design weight was 3,250 lb (1,474 kg), with bigger rotors the weight would have been more like 4,250 lb (1,928 kg). The aircraft was out of trim and the control incorrectly phased. The project was abandoned before it was flown because of financial and technical difficulties. Power was to be provided by two Gipsy Major engines 145 hp.

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5.8 The Wallis Autogiros (1958 -)

No treatise on British rotorcraft would be complete without mention of the Wallis Autogiros. These were a serious attempt to bring the gyroplane into sport and general aviation, driven by the enthusiasm of K. H. Wallis. Having built an American Bensen Gyro-Copter in 1958, Wallis produced his own highly modified and improved model, and proceeded to try to invoke the interest of the British Army. A batch of five were built by the Beagle Company and evaluated by the Army Air Corps for spotting and liaison work, but the evaluation was not favourable and failed to result in an order. Wallis continued over the ensuing years, producing a range of models of similar configuration with various power units (75-100 hp) as single and two-seaters (Figure 5a). Most of the Wallis autogiros were small, <500 lb (225 kg) with a rotor diameter of 20 ft (6 m). More than 25 have been built and many are still flying in the U.K.

Ken Wallis was a unique individual, who maintained strict control over his own product, much of which he constructed with his own hands. He has held no fewer than 34 FAI world records and many patents; he has continued to fly well into his 90s.

5.9 Light Gyroplane activity

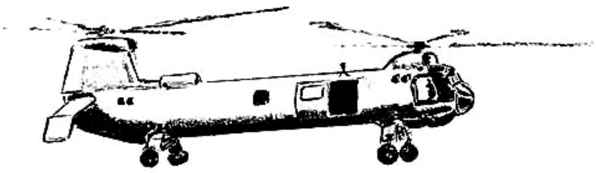
In the mid 1950s, light gyroplanes began to appear on the scene, weighing less than 1,000lb (500kg). A Gyroplane, unlike a helicopter, cannot properly hover. On the other hand it can take advantage of its low speed qualities to land and take-off in very short distances. Whilst they are aerodynamically fearsomely complex, mechanically they are very simple, and therefore not expensive compared to some other forms of flying. These are some of the qualities that attracted people to gyroplane flying, and had immediate appeal to the recreational flyer. The fact that many became available in kit form for home construction added to this appeal and gyroplanes have appeared in increasing numbers on the General Aviation scene.

Several attempts have been made to apply their use commercially without success, and they remain the domain of the enthusiast. There have been a disproportionate number of gyroplane accidents, often caused by a low level of training, with consequent failures due to mishandling and piloting errors, all of which, rightly or wrongly, have cast doubt on their safety. Thus the operation, licensing, maintenance and training associated with sporting gyroplanes remain issues which will have to be resolved.

5.9.1 The Thruxton HDW-1 Gadfly (1967)

The Gadfly was a serious attempt to introduce a small economic gyroplane onto the General Aviation market. A basic test vehicle was built with a conventional two-blade teetering rotor head, and the aircraft was powered by a 165 hp Rolls-Royce Continental engine driving a pusher propeller. The airframe structure of the sole prototype was fairly primitive compared to the final intended design, but the project failed to progress beyond the ground running phase.

Cierva/Saunders-Roe Skeeter 1948 was the first helicopter oprated by the British Army.



Bristol Type 192 Belvedere 1958, gave the RAF its first capable heavy-lift helicopter.

The Fairey Rotodyne 1957. ‘Technology before its time’. Tip-jet drive, innovative and fast. The promise of the Rotodyne remains unfulfilled half a century later.

Both aircraft were derived from the Saunders-Roe P-531 1958 and the development was completed by Westland.
The Scout, for the army in 1963, and the Wasp for small ship operations for the Royal Navy 1964.

Gyroplanes have been part of the rotorcraft scene since the late 50s.
One of the champions of the genre being Ken Wallis.

Figure 5a Westland License build activities and Gyroplanes 1948 - 2009

5.10 Westland Aircraft (Helicopter activity 1946 – 1960)

The Yeovil based company Westland Aircraft was another of Britain's long-standing aircraft companies, having been continuously involved in the manufacture of aircraft, and later helicopters, from the same site since 1915. In 1946 the company made a policy decision to re-direct its interest from fixed-wing aircraft to helicopters. At the time it was still deeply involved in the production of the Wyvern fighter for the Royal Navy. However, Westland pursued a different approach to any of the other British companies entering the helicopter field at that time, in that they arranged a licence agreement with Sikorsky, USA, to build their S-51 helicopter, with a remarkably generous clause allowing them to market the aircraft worldwide outside North America.

Westland installed the British Alvis Leonides engine and during 1949 produced 30 aircraft on a speculative basis. Three of these were evaluated by the British military and this led to substantial orders for the Royal Navy and Royal Air Force as the **Dragonfly**. The entry into service with the Royal Navy had a far reaching effect as helicopters immediately took over the task, normally undertaken by destroyers, to follow aircraft carriers in the rescue role during 'Flying Stations'. This forced home the potential of helicopters at sea, which would eventually lead the Fleet Air Arm to become virtually an all helicopter service.

A total of 149 Dragonflies were built and the basic design was further modified to become the **Widgeon,** Westland's own five seat version of which 15 were built. Success with the Dragonfly convinced Westland that there was a need for a larger machine, which could be met by adoption of the Sikorsky S-55. Again Westland adapted the aircraft for British requirements, both civil and military. The first **Whirlwind**, as it was now called, was flying by November 1952, and within two years the first Westland built Whirlwinds were entering service with the Royal Navy and the Royal Air Force.

The Whirlwind gave the British services a whole new outlook on the helicopter and its uses; it not only transformed the Search and Rescue role, but introduced the Dipping Sonar for anti-submarine warfare. The immediate outcome of this decision was to eliminate the need for fixed wing anti-submarine aircraft, and eventually led the Royal Navy to dispense with large aircraft carriers altogether. Westland continued its policy of improvement, initially in terms of power and rotor improvements, but of greater significance was the installation of the Rolls-Royce Gnome gas turbine which transformed the aircraft in terms of performance and reliability to the extent that it was even considered suitable for use with the Queen's Flight. Whirlwinds remained in service until well into the 1970s and a total of 364 were built.

The success with the Whirlwind established Westland as a major force in the helicopter business, and the need for continuing improvement of equipment for the British services caused them to look at the Sikorsky S-58. The process of adaption and improvement was repeated by the installation of the Napier Gazelle to produce the **Wessex Mk 1** as an anti-submarine helicopter for the Royal Navy, entering service in July 1961. The improvement went even further with the Wessex Mk2, which was fitted with Twin Rolls-Royce Gnome turbines. Several versions of the Wessex were produced and sold worldwide; a total of 382 were produced and a few remained in service until 2001.

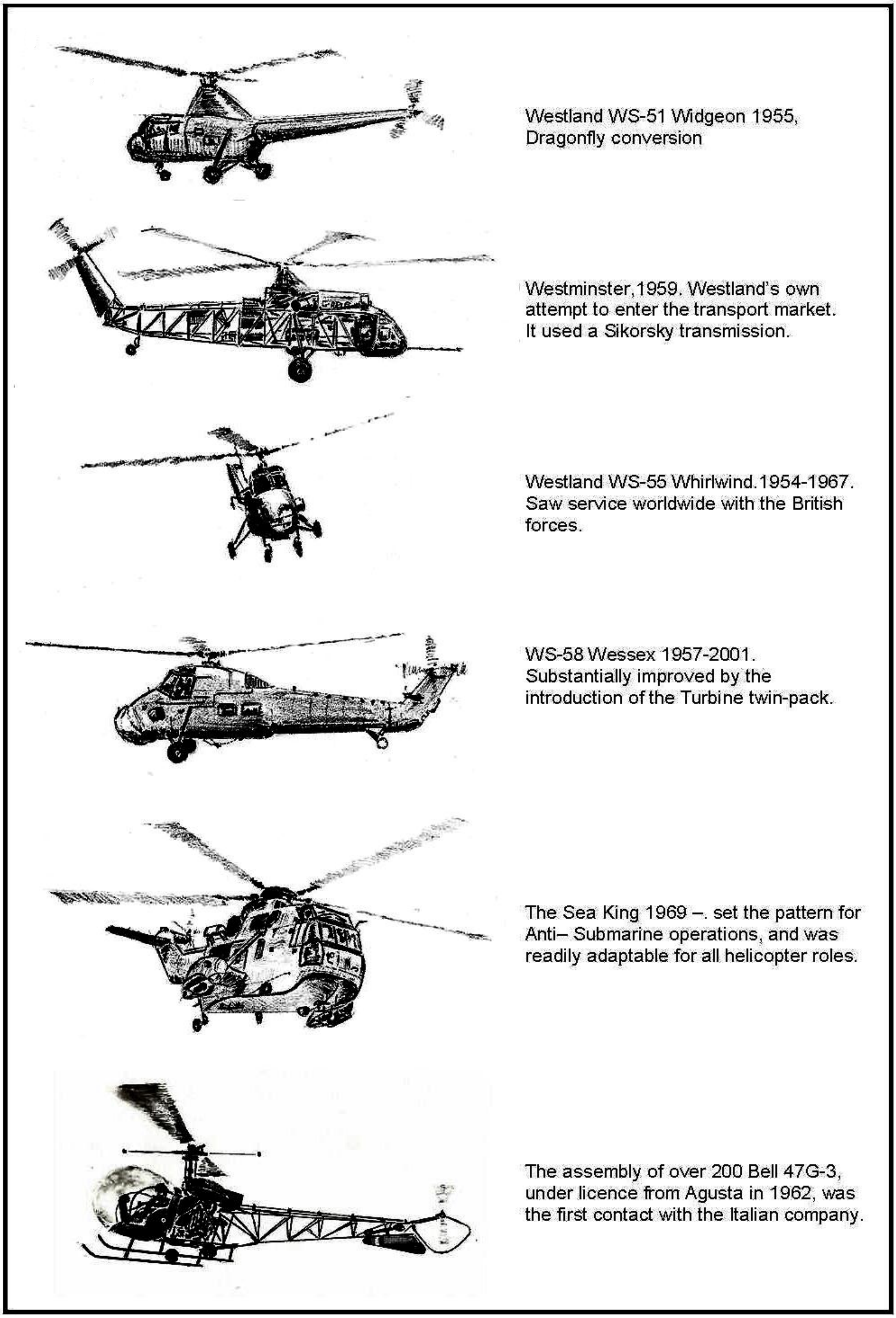


Figure 5b Westland License build activities 1948 - 2009

In 1955 Westland decided to embark upon the design of a large helicopter as a private venture. The result was the **Westminster**, with an all-up weight of 33,000 lb (14,969 kg) and a Westland designed fuselage; with a projected capacity for 40 passengers, it was aimed at the civil and military transport market. The transmission from the Sikorsky S-56 was adapted for two 3,150 hp Napier Elands. The first flight took place in June 1958 and two prototypes were built (Figure 5b).

6. RATIONALISATION (1960)

In 1960 the British aircraft industry was subject to a major upheaval. At that time there were more than twenty major companies producing aircraft, many maintaining a precarious hold on the business, chasing the few orders available, and in some cases having insufficient capital to invest in the future. The government of the time made it clear that the major military and state controlled airline orders would go to the companies which combined to form into larger, more viable groups. In the twelve months that followed, firms merged or were absorbed by larger groups until there were, with a few smaller independent exceptions, only two effective aircraft companies, namely the **Hawker-Siddeley Group** and the **British Aircraft Corporation**. Famous names such as Avro, Bristol, De-Havilland, Hawker and Vickers ceased to exist in their own right.

The helicopter industry followed its own course. Westland, by virtue of its production success and full order books, was the dominant helicopter company and proceeded to absorb the helicopter interests of Bristol, Fairey and Saunders-Roe, to become **Westland Helicopters**, Britain's sole helicopter company.

7. THE WESTLAND YEARS (1960 - 1994)

There now followed a challenging period, while the new and very much larger group of companies was reformed. The first consequence was that the Saunders-Roe factory at Eastliegh was closed, and work on the Scout and Wasp helicopters was transferred to the Fairey factory at Hayes. The Bristol facility at Weston-super-Mare was reduced in size and restricted to support of the Sycamore and Belvedere, both of which were nearing the end of their service lives. Yeovil became the headquarters of the reformed Westland Helicopters, devoted to the production of Whirlwind and Wessex. One of the first major decisions made on behalf of the new company was to abandon development of the Westminster in favour of the Rotodyne, which itself was finally cancelled in 1962 due to lack of official support.

During the period 1962 - 1965 the production facility at Yeovil was busy with Wessex, and there was a major development programme to produce the major update in the form of the **Wessex Mk3**, which included fully automatic transition capability.

The Army Air Corps finally decided upon their choice for a Unit Light Helicopter, selecting the American Bell 47G. This aircraft was being manufactured under licence by Agusta of Italy, and a sub-licence agreement was made for Westland to produce these at Yeovil as the **Sioux**. Completion of this order for over 250 aircraft brought the number of helicopters made at Yeovil to over one thousand.

The WG13 Lynx 1971, had a semi-rigid rotor, and developed into a fast and highly manoeuvrable helicopter.

The Naval version set a new standard for small ship operations.

The Super Lynx, incorporated new engines, advanced technology blades and a comprehensive avionics fit.

The Gazelle was part of the Anglo-French Helicopter deal in1970, which resulted in production of Lynx , Puma and Gazelle by Westland.

The Westland 30 (1980) was an attempt to enter the civil market with Lynx technology. Its limited success was at the heart of 'The Westland Affair'.

The AW-101 Merlin, designed and developed with the Italian firm Agusta symbolizes the future of the British helicopter industry into the 21st century.

Figure 6 Westland Helicopters and International Collaboration 1970 - 2009

Having established the helicopter as a primary anti-submarine weapon for the Royal Navy with the Wessex, consideration was given to the next generation of aircraft. With this in mind the licence with Sikorsky was extended to build the **SH-3D Sea King**. Four airframes were purchased from Sikorsky and modified to the British standard, to take Rolls-Royce Gnome engines with electronic fuel systems and a comprehensive electronic fit including radar. The Sea King was produced for the British services and for export in the Anti-submarine, Tactical Transport and Search and Rescue roles. A total of 330 were built before production ceased in 1996 and even then it was set to remain in service well into the next century.

A Defence ‘White Paper‘ identified the requirement for a wide range of helicopters for the British services, including a Medium Support helicopter for the RAF, a Utility helicopter for the Army, a Small Ships helicopter for the Navy and a Unit Light Helicopter/Trainer. Westland was already working to near full capacity on the production of Wessex and Sioux at Yeovil, and the manufacture of Scout and Wasp helicopters at Hayes. Work had however been put in hand to satisfy the Utility/ Small Ships requirement with one aircraft, the **WG-13**, which had already been the subject of a wide range of project studies, and the final selection was visible in mock-up form at Hayes.

The cost involved in the design and development of aircraft to meet the full range of requirements for the UK armed forces would have been colossal, and so the MoD procurement authorities began to look elsewhere for suitable aircraft. The French company **Aerospatiale** was working on two helicopters to satisfy French requirements for Support and Light helicopters, both of which were suitable to meet British needs. Even more significant was the fact that Britain had joined the European Community, and so it was that with the support of the two governments the **Anglo-French Helicopter Package Deal** was struck. The UK was to order the French **Puma** and **Gazelle** and the French Navy was to order the WG-13. The deal included a considerable amount of involvement in development and production in both countries with all the aircraft. Most important was the fact that the Design Authority was to remain with the parent companies. Aerospatiale retaining responsibility for Puma and Gazelle, and Westland responsibility for WG-13, which was subsequently named **Lynx.** The Anglo-French Deal involved the production of over 200 helicopters for the British requirement alone, and heralded a period of unprecedented prosperity for Westland throughout the 1970s. The original French requirement included plans for an **Armed Attack Version**, but this was abandoned early in the programme.

The Lynx flew for the first time in March 1971, followed by a five year development programme, during which it evolved into one of the world’s most effective small-ships helicopters. Most important was the introduction of an all titanium semi-rigid rotor, which set a new standard for manoeuvrability and control response. Lynx achieved success in the world’s markets and continues to be in demand, with over 450 built to date.

Westland began design studies to utilise the proven Lynx dynamic system as the basis of a larger helicopter for the civil market, taking what for Westland was the unusual commitment of a ‘Private Venture’. This became the **Westland 30**, which had a considerably larger cabin, capable of carrying 17 passengers; the prototype flew for the first time in April 1979 and in the next two years of development achieved certification in Europe and the USA. A total of 40 were built but orders never came in sufficient numbers to cover the large development costs.

The failure of the Westland 30 to realize its potential put Westland into a difficult financial situation. With Lynx and Sea King production slowing down, there was a potential five year gap during which there would be few aircraft under construction. This in turn presented a severe cash flow problem and it was clear that Westland Helicopters would need to combine with another major company to ride the lean years. The Westland management favoured working with Sikorsky, but an influential element within the British government wanted a European option. This led to the infamous "Westland affair" of 1986, which brought about the resignation of two senior government ministers. At the end of it, Westland Helicopters was allowed to take up its preferred option to work with Sikorsky who became a major shareholder. This resulted in the restructuring of Westland as a company but with this came additional work for Sikorsky and in particular an agreement to build the **WS-70 Blackhawk** helicopter to support a large contract with Saudi Arabia.

The outbreak of the Gulf War brought about a marked change in the political and commercial situation. Sikorsky gave up their holding in Westland, but also withdrew the licence to build and sell Blackhawk.

While all this was happening, work was in hand to develop the use of composite materials for the construction of main and tail rotor blades. The British Ministry of Defence was keen to encourage this work and placed a contract, which included considerable assistance from the MoD, to produce a composite blade for the Sea King, albeit that it was to be simply a Carbon Fibre/Composite replica of the existing metal blade, identical in profile and stiffness. This was successfully achieved and composite blades were introduced across the Westland built Sea King fleet.
What the Sea King re-blading exercise did achieve was to establish an understanding of the technology and the facilities required to create a new standard of main rotor blade. The move to composite blades was occurring worldwide, and the Sea King exercise was the start of a co-ordinated exercise with the Ministry of Defence working with Westland on a new project, **The British Experimental Rotor Programme (BERP).**

Subsequent developments of the BERP blade were designed to take full advantage of all the benefits to be gained from composite construction, with which it was possible to vary the aerofoil section along the length of the blade to suit the flight regime and also to accurately manufacture the complex profile necessary for the section of blade subject to high Mach numbers, at the tip.

After a long period working with the Ministry establishments at Farnborough and Bedford, a satisfactory standard of BERP blade was made and test flown on a Lynx. The success was such that in August 1986, a Lynx captured the World Absolute Speed Record at an average speed of 216.3 kt (400. 87 km/h). This record has now stood for over twenty years. Since that time the majority of Lynx aircraft have converted to BERP blades.

Once a new weapon system has become established in squadron service, it is necessary to start considering its replacement. By the late 1970s the Sea King had been in service with the Royal Navy for ten years and had already undergone several service updates, and although it clearly had a long service life ahead of it, the time was right to consider its replacement. In 1977 Naval Staff Requirement 6646 was issued, detailing a substantially larger aircraft to carry the next generation of ASW equipment, with increased performance and capability. Westland responded with **WG 34**, considerably heavier than the Sea King but with the added complexity of small ship capability.

It quickly became apparent that to answer the UK requirement in isolation would be prohibitively expensive and so it was decided to look for an international partner with a similar requirement. The Italian Navy was already operating a derivative of the Sea King manufactured under license by Agusta and was in the process of drawing up a requirement for its replacement. Westland had previously worked successfully with Agusta in the 1960s to produce the Sioux. Following a series of inter-company discussions, the British and Italian governments signed a Memorandum of Understanding (MOU1) in November 1979. This action led to the formation of a joint company in June 1980 named **EH Industries,** to manage the development, production and marketing of the new helicopter to be designated **EH 101**, intended not only to respond to the maritime requirement, but also for civil and military transport applications.

It is worth considering the political scene at this time. Soviet Russia was the primary threat, a particular concern being the containment of submarine activities from its northern bases. The Berlin Wall was in place and the central European plain was seen as a possible battlefield. Sadaam Hussain, if not our ally, was at least accepted as a trading partner, whilst Yugoslavia was seen as a viable and cohesive nation. The situation in the Middle-East was at least in a state of armed stability. Such was the environment against which the requirement for the new helicopter was drawn up, and this typifies the dilemma for those charged with procurement of equipment which, even with a fair wind, is unlikely to be in service in less than a decade from the point at which a decision is made.

The 1980s were also a defining moment in technical development with regard to rotor design, materials and in particular avionics. The new generation of helicopters would be software-driven to an extent hitherto unthought of, demanding new skills of designers and managers.

In June 1981, the EH101 project definition phase was entered, the requirement for the two navies was laid down and the tough negotiations regarding allocation of workshare were resolved. Over the two years that followed much of the design work was undertaken, the avionic design representing as much as fifty percent of the effort. The workshare issue was in itself interesting. Westland was keen to undertake a significant part of the avionics task, but to take it on in its entirety would preclude full involvement with the airframe design. For Westland to maintain its place as a platform manufacturer, and in particular to ensure that the world beating BERP blade technology was retained, it was necessary to compromise. Agusta was very keen to undertake the transmission. The workshare discussions were to say the least lively, but it is a measure of the way in which the two companies were able to work together that an acceptable plan was evolved.

In 1984, MOU 3 giving the full go-ahead for the design and development was signed, and manufacture of the pre-production aircraft commenced (nine in all, four in Italy and five in the UK). The first aircraft (PP-1) flew from Yeovil in October 1987, quickly followed by PP-2 in Italy in November; by 1990 eight aircraft were flying on the programme.

As early as 1988 it became apparent that some important aspects of the basic development such as performance, handling and stress data gathering would be best served by operating the appropriate aircraft from a single site. The fact that the main transmission items were produced and maintained in Italy, coupled with the climate and availability of high altitude test sites, resulted in PP-1 joining PP-2 at Cascina Costa, where a joint Westland and Agusta team worked together for two years.

It is generally accepted that one should avoid developing a new aircraft with a power-unit which is itself under development. In the case of the EH-101, the original specification called for three General Electric CT-7 engines of 1,720 shp, so it was thought that this problem would not arise. However, half way through the programme it was decided that the UK military aircraft would have the new 2,100 shp RTM-322. Plans were put in place to install the new engines in PP-4 and PP-5, and the additional installation lay-ups and integration work added to the already tight programme. Other specification changes included a late decision to include dunking sonar in the RN aircraft.

By 1990 much of the development programme was either complete or well in hand, and discussions were in place to decide upon a prime contractor for the Royal Navy's aircraft. It was a condition that the Prime Contractor must have sufficient financial resources to underwrite any shortfall in compliance, and even the combined resources of Agusta and Westland could not meet this condition. There followed a competitive process to decide the issue and after some protracted discussions the contract was awarded to IBM (subsequently to become Loral and finally Lockheed-Martin). The production order for 44 **Merlin HM Mk1s** was eventually placed in 1992. Agusta had taken the lead in the development of the Utility (Transport) variant, with its rear-loading ramp. Two of the pre-production aircraft (PP-7 and PP-9) were built to this standard. By the early 1990s Westland were working hard to cultivate interest from the RAF for Merlin (as it was now named) to satisfy a requirement for a medium lift, high performance helicopter. In late 1994 an order for 22 aircraft was placed. By this time Westland was part of the GKN group, whilst Agusta had been strengthened by becoming part of Finmeccanica. The result of this was that EHI could now successfully bid to become Prime Contractor.

Reliability and maintainability had always been an important part of the EH-101 specification, with severe cost penalties against any shortfall. An important part of the programme was the inclusion of maturity trials, which were undertaken during 1998-2000. Two aircraft (PP-8 and PP-9) were subjected to intensive flying, initially in Southern Italy and later in Northern Scotland. The two aircraft accumulated more than 2,000 hours each.

The full civil potential of the EH101 has yet to be realised. A civil machine was delivered to Japan, and PP8 gained limited certification to demonstrate the very high standard of passenger comfort achievable in this new generation helicopter. After a false start in Canada in 1993, the **Cormorant** was ordered to meet the tough Canadian Search and Rescue requirement. Production Cormorants were delivered direct from Italy by self-ferry across the Atlantic. Orders were also confirmed from Denmark and Portugal.

8. GKN-WESTLAND (1994 – 2001)

The international engineering firm Guest, Keen & Nettlefold (GKN) had been a major holder in Westland for some considerable time, with a GKN representative on the board of management. The company already had extensive interests in agro-technical products, automotive engineering and defence vehicles. In March 1994, GKN succeeded in a full take-over of Westland Helicopters, to become part of the GKN group. The move to GKN was well timed. Negotiations were in hand to supply the Merlin for the Royal Air Force as a medium transport, and the selection process was under way for an Attack Helicopter for the Army, for which Westland had already joined with Boeing (formerly McDonnell-Douglas) to build the AH-64 Apache, modified to UK requirements. With the commercial strength of GKN available, the new company, **GKN-Westland** was in a position to bid for the role of Prime Contractor for both aircraft. By 1996, deliveries of Merlin HM Mk1 for the Royal Navy were under way (44 aircraft), and contracts had been signed for the Merlin HC Mk3 for the Royal Air Force (22 aircraft).

The Attack Helicopter contract was awarded to GKN-Westland, to produce 67 **WAH-64D Apache** helicopters for the British Army. The UK version of the aircraft was to include the 'Longbow' radar, a comprehensive defensive aid installation, and avionics to UK requirements, and was modified to accept the RTM-322 engine. The Apache contract also included a long-term training and support programme.

The Lynx was also subject to a considerable amount of activity. Several export customers were attracted to the proposal to provide a full rebuild with a life extension, and in many cases this included upgrade to **Super-Lynx** standard. A programme to introduce the T-800 engine was satisfactorily completed and orders were received for new build Super-Lynx 300. The Lynx fleet in the UK was aging, and a replacement aircraft was clearly going to become an urgent requirement. A proposal was made by GKN-Westland to offer a complete comprehensive rebuild of the Lynx, which was to include a fully re-designed fuselage, common to both Army and Navy variants, as well as T-800 engines, BERP-4 Blades and fully integrated avionics.

9. AGUSTAWESTLAND (2001 – 2005)

In February 2001, GKN agreed with the Italian firm Finmeccanica (the parent company of Agusta) to form a new European based company, combining the helicopter resources of Agusta and Westland under the name AgustaWestland and thereby creating a large helicopter manufacturing group, which could compete in the global market.

During that time, AgustaWestland were successful in winning the competition to provide 23 **VH-71 (EH-101 VIP)** helicopters for the US Presidential fleet. The Prime Contractor for this activity was Lockheed-Martin. The first six airframes were built in Yeovil, and the plan was to complete the rest in USA. However the outcome of the competition was fiercely challenged by the US industry, and in particular Sikorsky. As time progressed the programme went seriously over budget, perhaps in part because of aspects of the US contractual system. The outcome was that with the programme incomplete, all activity was stopped and the six completed aircraft were placed in store while the future plan is considered as the companies re-submit their competitive proposals.

10. FINMECCANICA (2005 – date)

The story completed its cycle when in 2005, GKN sold their holding in AgustaWestland to Finmeccanica, with the result that the UK elements responsible for helicopter design and development are now essentially part of an Italian company. The name AgustaWestland has been retained and the two companies (Agusta and Westland) have fused together well, with a significant interchange of design and development work between the two sites.

An order has been placed by the UK government for what was known as 'Future Lynx', calling for 62 aircraft designated **AW 159 Wildcat.** What was known as the EH-101, now carries the designation **AW-101** and work is well in hand to clear the aircraft to operate at higher all-up weight, and to incorporate technical improvements, including BERP 4 blades.

11. THE INFLUENCE OF THE AW139 AND ITS VARIANTS

In 1998 Agusta entered into an agreement with the Bell company to start work medium sized twin engined helicopter (6,000 kg/14,000 lb auw, 14 passengers) for the civil market to replace the range of helicopters serving the market pioneered by the Bell UH-1 Iroquois. The programme went well, and the first aircraft flew in 2001 by which time Agusta had acquired full responsibility for the project, now designated AW139. The first aircraft were delivered to customers by 2003, and by 2010 orders had been placed for over 400 aircraft.

Agusta have followed up the success of the AW139 with two similar aircraft, the AW169 and the AW189 (approx.: 4,500 kg / 8,800 lb & 8000 kg / 17,600 lb respectively). The result is that the company now has a range of aircraft to meet the requirements for law enforcement, SAR, air ambulance and transport operations against any specification a customer may stipulate.

Westland experience in the civil market has never been particularly rewarding, most of the work at Yeovil being devoted to Military projects. With their new found success, Agusta have included Westland in plans for the 169 and 189, together with the intention to establish a civil maintenance and overhaul facility.

12. IN CONCLUSION

It must be appreciated that the helicopter industry, worldwide, is multinational, regardless of geographic location. Few major projects proceed without international collaboration. In 2015, Yeovil will celebrate 100 years as a manufacturing site for aircraft and helicopters.
The resources for helicopter design and manufacture sited in the UK retain their British identity and can only benefit from the strength of the support now available from their large commercially strong parent company.

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All illustrations by the author.

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He worked on the Rotodyne with Fairey and subsequently Westland, to be involved in the entire range of Westland products, retiring in 1993 as Chief Flight Test Engineer. He was awarded the 'Kelly Johnson' award for outstanding achievement in his field by the Society of Flight Test Engineers, the first recipient to receive the award outside the US and has since been awarded Fellowship of the SFTE.

David presented the 43rd 'Cierva' Lecture to the Royal Aeronautical Society in 2003.
Living in Somerset he has continued to work as an aviation artist, flight test consultant and flight historian.

In 2001 David was confirmed as having Parkinson's Disease, a fact that he likes to make known, and in spite of his affliction he continues to lead a full and active life.