Elliott Flight Automation Limited
A Brief History, 1804- 1985

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This history was originally produced by Mr Broadbent and was updated by Mr C.R. Reese in October 1995. This version incorporates comments from one of the directors, Mr R W Howard as well as some from Mr C.T. Bartlett.

1. Past History

The name "Elliott" stems from William Elliott, who had been apprenticed as a compass and drawing instrument maker and set up in business near Holborn about the year 1804. The business prospered and before long the Company was producing most of the standard optical, surveying, navigational and "philosophical" instruments for home and overseas customers. It became well enough known to be called on to provide experimental equipment for leading scientists including J. C. Maxwell, Charles Wheatstone, J. W. Strutt and Lord Rayleigh. William Elliott took his two sons into the business which was heavily involved in producing instruments and equipment for the new industries of power generation, electrical traction and telegraphic communication. The Company took over the old-established business of Watkins and Hill, followed later by Theilers who made telegraph equipment. After several changes of address within central London, the business transferred at the end of the century to new premises at Lewisham in South-East London and there, although with changes of ownership, it continued until 1990.

By the end of the 19th century it was no longer a family business but the managers of the day must have been alert to possible new fields of activity. As early as 1910 a panel of Elliott instruments was being offered as an 'optional extra' by Short Brothers, who had established the first aircraft factory in the world, making aeroplanes based on designs by the Wright Brothers; and Elliott's advertised in early issues of the new magazine 'Flight'. The Elliott Instrument Panel was installed on the world's first 'stable' aircraft design, the Royal Aircraft Factory Be2. This area of activity received an impetus during the first World War, by the end of which the range of instruments included altimeters, tachometers and fuel flowmeters.

Shortly afterwards it seems that interest in aircraft instruments was allowed to flag, possibly owing to a greater concentration on Admiralty business. Between two World Wars, the Company, now styled Elliott Brothers (London) Limited, continued to manufacture electrical measuring instruments, but became expert in mechanical analogue computers (as they would be known today) for the control of naval gunnery. As a result, the Company was overwhelmed with naval work during the Second World War and devoted virtually all its efforts to this type of equipment.

At the end of the war, the Company was badly placed to re-enter the commercial market. A Research Laboratory was established at Borehamwood, but an obsession with Admiralty work still remained. Most of the activity over the next few years was devoted to gunnery director work, involving microwave radar, servomechanisms, a stable platform with digital transmission of angular data, magnetic amplifiers, and first steps towards special-purpose digital computation using thermionic valves. However, research work was not likely to produce any volume of production in the short term, and the rapid decline of production orders at Lewisham presented the Company with a very serious situation. In an attempt to re-establish the Company on a sound footing a new management team was introduced. In retrospect, it can be seen that it was this action that led to Elliott's re-entry into the aircraft instrument field, and the eventual formation of Elliott Flight Automation Limited. To make this clear it is necessary to retrace a few steps in time.

2. Origins of Elliott Flight Automation Limited

In 1930 Leon Bagrit had founded the Swift Scale Company for the manufacture of commercial scales and weighing machines, in the conviction that with a good product and aggressive marketing it would be possible to compete with established manufacturers. In spite of the period of trade depression the business became established.

During the Second World War the manufacturing company, styled B & P Swift Limited turned to war work, and manufactured aircraft equipment for the Ministry of Aircraft Production. This included flap and undercarriage actuators, which called for good gear and screw-cutting facilities, for which the Company, though small, developed a high reputation.

At the end of the war, the aircraft industry began the design of larger and faster aircraft, and it began to appear that pilots would have difficulty in controlling them because of the larger forces required. The Ministry of Supply therefore initiated the development of electromechanical power assisters and placed a contract with Swift. This contract represented the first aircraft design work undertaken by the Company and installations were completed in a large flying boat built by Short Brothers, the 'Shetland', and Tudor' commercial airliners built by A V Roe.

3. Early Days

In 1948 Leon Bagrit became Managing Director of Elliott Brothers (London) Limited, and began the task of saving the Company. The future of the instrument business was thought to be in the wider exploitation of automatic control methods, 'automation' as it came to be known - and two policies were necessary to make the Company less vulnerable, the rapid acquisition of new product lines by the manufacture of established designs under licence, and the diversification of markets to spread the risk. First expansion lay **in** the field of instruments for industrial process control and fluid control valves, but within a short time a batch of aircraft autopilots were being made from a design by the Royal Aircraft Establishment (RAE).

Immediately after the end of the war there had been a great upsurge of activity in guided weapon development, and RAE had foreseen that there would be a need for radio-controlled 'drone' pilotless aircraft on the lines of the pre-war 'Queen Bee' for use as targets in guided weapon trials. The design of an autopilot for this purpose. Type A had been started, but had been shelved subsequently since no particular requirement existed. In 1948 the specification was issued for a small jet-propelled target aircraft, the 'Jindivik', to be designed and built in Australia. A revised version of the Type A autopilot, Type B, was completed for this purpose, and Elliott Brothers was entrusted with manufacture of a development batch.

In August 1950 a design study contract was placed on Elliott Brothers which opened a new door. This was for a special-purpose visual bombsight for installation in the English Electric 'Canberra'. The problem was a difficult one and did not lead to any development, but it represented an entry into the bomb-sighting field from which stemmed further work with major consequences.

With the introduction of aerodynamically 'clean' high-speed aircraft such as the Gloster 'Meteor' it was found that their ‘short period’ instability in flight left something to be desired, especially for weapon-aiming purposes. In particular, they suffered from a low amplitude combined rolling and yawing motion known as 'Dutch roll', and RAE investigated a method of stability augmentation by means of a quick-response actuator operating on a rudder trim tab, controlled by a gyro measuring rate of yaw (possibly with a component of roll rate as well). Experiments were successful, and once again Elliott Brothers was asked to manufacture a development batch of autostabiliser equipment.

This work, together with the current work on autopilots, justified the establishment of a separate manufacturing unit at Lewisham, initially known as Aero Division. When a large production order for autostabiliser equipment was received insufficient space could be found at Lewisham, and the unit was soon transferred to Rochester. At the same time the name was changed to Aviation Division. The rate gyro for the autostabiliser was developed by the RAE from the K23 Gyro, WWII design made by Siemens, and was still in production virtually unchanged until the mid 1970's.

4. Branching Out

During 1952 the Company had tendered for the development of two models of a stable reference unit, one for lighter aircraft and one for bombers. This was to take the form of a gyroscopically-stablized platform carrying accelerometers and attitude-measuring transducers, to serve as a central source of data for other navigational and weapon-aiming equipment. A contract for the bomber version was awarded, and a team formed at Borehamwood to carry out the development. This was successfully completed with the testing of Master Reference Gyro Type B, but did not lead to production: nevertheless, the experience gained laid the foundations for later work on other stable platforms which have been produced in reasonable numbers.

In 1952 work was started, in conjunction with a team at RAE, on the development of the control system for a new type of guided bomb. This was to fall freely from an aircraft but was steerable towards a pre-defined target by means of movable surfaces controlled by an automatic navigator. The calculation of distance to be travelled towards the target was to be achieved by double integration of signals from accelerometers mounted on a gyroscopically-stablized platform. This was therefore a true 'inertial' navigation system; but could be relatively primitive, since errors would accumulate only during the time of fall. Equipment in the aircraft of some complexity was required, including a visual sighting head and a control unit to feed data signals to the bomb before release. In order to determine the maximum latitude attainable in the choice of aircraft position relative to the target at the moment release it was necessary to compute families of three-dimensional trajectories, given the aerodynamic characteristics of the bomb. For this purpose, a small digital computer was built at Borehamwood, with support from the National Research and Development Corporation. This was known as 'Nicholas', owing to the use of a nickel-wire delay-line store, and although it had a deplorably high failure rate it proved to be capable of carrying out the necessary calculations. This bomb project was cancelled before completion, just as a trials team was being assembled. The cancellation was a blow at the time, but the project led within two years to a logical successor, the powered bomb 'Blue Steel'.

With a view to rapid expansion of the range of instruments available for production manufacture in the Aviation Division, Elliott Brothers entered into licence negotiations with Bendix Aviation Corporation in the United States, since the products of their Eclipse-Pioneer Division were of interest. At that time Bendix were reluctant to licence their range of civil autopilot equipment, no doubt because the Aviation Division was obviously too small to provide the amount of application engineering required for a British installation, but offered an indicating accelerometer and a range of fuel flow metering equipment. The first was known to have an immediate market for British military aircraft in substantial numbers. The instrument called for a high standard of manufacture and provided an excellent training for production staff. The market for flowmeters was less certain, and a meeting was called in May 1953 to which representatives of aircraft constructors, engine manufacturers, and airlines, were invited. Their support was encouraging, and a licence was negotiated. Subsequently orders were received for flow metering equipment for the Handley Page 'Victor' and A V Roe ‘Vulcan’ bomber, and for some types of Vickers 'Viscount' civil airliner. The volume of work was far too much for the experimental fuel flow test rig which had been built, and in January 1957 a new Test House was opened at Rochester by the Minister of Supply.(Interestingly the

Eclipse Pioneer Mass Flowmeter was subsequently found to be based on a previous Elliott patent by Messrs Needham and Harris)

5. First attempts at exporting

It can be seen that by early in 1953 the Aviation Division was very active, but examination of the work in hand showed that it was almost entirely dependent on British Government contracts for military aircraft equipment. This was felt to be hazardous, so an attempt was made to open up an export market. The area selected was France, and the product autostablisers, with which the Company had now gained considerable experience. Orders were obtained for trial installations on four aircraft; Marcel Dassault 'Mystere IV A' and 'Mystere IV B', (fighters), SNCASO 'Vautour' (light bomber), and SNCASE 'Baroudeur' (miniature fighter). All of these installations operated satisfactorily, although optimum characteristics of the equipment could only be determined empirically, but unfortunately none of them led to production orders. (The later production system for the Mirage III used a Lightning design). The exercise had proved to be instructive and worth while financially, but had not achieved the main aim, that of providing a volume of production turnover.

6. More autopilots

The beginning of 1954 saw a fresh spurt of activity in autopilot design. At Borehamwood work had just been started on a brand-new autopilot specially designed for a new British fighter aircraft, the English Electric P1, destined to be known to the Royal Air Force as the English Electric 'Lightning'. 'This was the first autopilot/autostabiliser to be designed wholly by Elliott Brothers, and called for intensive study of aircraft stability theory, computer simulation, and the acquisition of an aerodynamicist for the first time. The influence of hydraulic power control units on the system had to be investigated, which entailed close liaison with the makers and installation of main units in the Borehamwood Hydraulics Laboratory. An Elliott-made analogue simulator was developed for stability studies and used extensively at Borehamwood and English Electric at Warton on subsequent autopilot developments.

In providing input signals to the 'Lightning' autopilot, use was made of Bendix experience in the design of air data computers. These were electro-mechanical analogue computers operated by capsule elements, used to measure altitude and airspeed and calculate signals representing, for example, true airspeed or Mach number, from basic pressure measurements. Early manufacture of licensed designs formed the foundation for an extensive range of Elliott-designed products of later years.

It had become apparent to RAE that variants of the Type B 'drone' autopilot would be required in some quantity. This was a fairly complex and expensive set of equipment, and consideration was given to possible development of a simpler and cheaper set. The Company carried out a design study and proposed a radically simplified design to be known as Type L, based on first principles. Test flying was carried out from Rochester Airport to demonstrate that the concept was sound, and development was allowed to proceed. This resulted in the forerunner of a series of 'drone' autopilots that are still in production, although the latest versions would hardly be recognizable as tracing their ancestry back to the 1954 design study.

Successful experience with the autopilot development for the 'Lightning' resulted in a further contract to develop an autopilot for a new naval aircraft, later to be known as the Blackburn 'Buccaneer'. At first this was expected to be merely an adaptation of the earlier equipment, but the low-level strike tactical application of the aircraft was entirely different from that of the RAF high altitude interceptor, so that the requirements soon proved to be incompatible. The 'Buccaneer' autopilot therefore become effectively a completely new design using germanium transistors and magnetic amplifiers. Both these military autopilot developments led to production runs extending over several years.

7. Inertial navigation : early experience

Early in 1955 the Company was fortunate in obtaining a Government contract for the development of automatic navigation equipment for a new weapon, the 'stand-off bomb named 'Blue Steel'. This was virtually a miniature pilotless aircraft, rocket propelled, which was to be dropped from a 'Vulcan' or 'Victor' bomber while the aircraft was still far from its target. The bomb was then to make its own way to the target independently of any further command guidance, by means of an automatic navigator controlling its autopilot. Since the intended time of flight would be substantial, the primitive type of equipment envisaged for the 1952 free-fall bomb would have been hopelessly inadequate, and it was necessary to develop a stable platform of very high precision to carry the accelerometers that served as a source of essential navigational data. Previous experience with the Master Reference Gyro, Type B, was of great value, and obviously contributed to the selection of Elliott Brothers as a contractor for this project. The development, including a period of flight trials carried out in Australia using a pre-production batch of equipment was necessarily lengthy, and was followed by an order for production quantities. This presented a formidable task, calling for a rapid expansion of manufacturing facilities at Rochester, both for mechanical engineering work of superlative quality and for electrical and electronic assembly.

8. Divisions and Mergers

It will be apparent from the foregoing that towards the end of 1958 the Aviation Division was heavily engaged on several fronts. A merger had recently been effected between Elliott Brothers' interests and those of Associated Automation Limited, the combination of companies being named Elliott-Automation Group. A key policy in building up this group had been the establishment of semi-autonomous Divisions for the exploitation of different areas of the overall instrument and automation market, and it was felt that the magnitude and spread of the Aviation Division's business was now sufficient to justify further subdivision. Accordingly, the Aviation Division was split into four Divisions, Aircraft Controls, Inertial Navigation, Aircraft Engine Instruments and Aviation Service and Repair, each to be run by its own Divisional Manager under overall direction from a central management. The last of these Divisions had started life as a Repair Section and had been built up initially by overhauling Bendix instruments from North American 'Sabre' aircraft, then in service with the RAF. It now occupies extensive premises at Rochester and this whole period saw a gradual movement of Divisions to the new site.

This process of subdivision was repeated in later years. After a short life. Aircraft Controls Division was split into two, Transport Aircraft Controls and Military Aircraft Controls.

In 1970 TACD was merged with MACD to form Flight Controls Division (FCD) but the combat aircraft business was again separated in late 1979 or early 1980 to form Combat Aircraft Controls Division (CACD) and the remaining military business was transferred to CACD in 1991. The Phoenix drone was however managed within FCD.

Four new Divisions were formed in 1961 Gyro, Automatic Test Equipment, Airborne Computing and the Environmental Research Laboratory, later to change its name to Flight Automation Research Laboratory when its scope was broadened.

In 1973 the Airborne Computing Division was renamed Maritime Aircraft Systems Division (MASD) to more nearly represent its major business area. Gyro Division merged with Inertial Navigation Division (IND) to become Guidance Systems Division (GSD) in 1984 and this was merged with Airborne Displays Division (ADD) to form Guidance and Displays Division (GDD) in 1992.

With the growth in the number of Divisions devoted to aircraft equipment, a separate management company was formed in 1962 and named Elliott Flight Automation Limited.

In the same year Elliott-Automation acquired Firth Cleveland Instruments Limited and changed its name to Elliott (Treforest) Limited. Two years later the aviation interests of this company were absorbed by Aircraft Engine Instruments Division.

Also, in 1962 Flight Instrument Division was established, primarily to market air data sensors and computers.

Later three more Divisions were formed, Airborne Display, Precision Test Equipment and Fuel Flow Laboratory. The test equipment and display Divisions were subject to a succession of amalgamations and fissions as their workload varied: first Precision Test Equipment and Automatic Test Equipment were combined to form Flight Support Equipment, then Airborne Display was added to form Flight Data Analysis and Display Division, and finally this was split to form once again Automatic Test Equipment and Airborne Display, on the acquisition from Rank Cintel Limited of their aviation display business. ATED grew substantially during the 1970's and 1980's with the large amount of work on Tornado but the completion of that programme saw a decline during which it changed its name to Support Equipment Systems Division (SESD) in 1990 and was absorbed into the Logistic and Customer Support Division (LCSD) in September 1991.

Airborne Display Division (ADD) became the largest GAv Division but the defence cut backs of 1991/92 resulted in its merger with Guidance Systems Division (GSD), (previously the Inertial Navigation Division) in 1992 to form Guidance and Displays Division (GDD).

The Fuel Flow Laboratory was absorbed into Aircraft Engine Instruments Division in 1966.

AEID, in turn, was combined with Flight Instruments Division (FID) in 1970 to form Instrument Systems Division (ISD). Within this division a new Oil and Gas business was initiated with the winning of a contract from BP for a wellhead control system for the North Sea Magnus field. Because of lack of space and resources the business was moved to Nailsea as the Offshore Projects Group (OPG). In 1972 Powerplant Systems Division (PSD) was formed from the relevant projects in ISD such as the development of digital engine control computers.In 1989 PSD absorbed the Offshore Projects Group to become Monitoring and Control Division (MCD), which later encompassed also the Power Conversion Systems Division (PCSD) and Recording Systems Division (RSD) which had also been set up at Nailsea in 1984 and 1982 respectively. Owing to a downturn in the Defence business this division was absorbed by ISD in 1992 while the Oil and Gas business, which was beginning to grow rapidly, became a separate division.

Elliott-Automation merged in 1967 with the English Electric Company Limited, and the combined group was taken over by the General Electric Company Limited in 1968 as a subsidiary ol GEC-Marconi Electronics Limited, but a year later was grouped with kindred divisions of The Marconi Company to form Marconi-Elliott Avionic Systems Limited. In April 1978 the company was renamed Marconi Avionics Limited, with Dr Bernard O'Kane, Chairman and Jack Pateman, Managing Director.

There was steady growth to nearly 12,000 employees in 1982. The name was again changed to GEC Avionics Limited in August 1984 and the Basildon establishment was separated to form GEC Sensors Limited. As a result of the cancellation of the Nimrod AEW programme in December 1986, most of the operations at Borehamwood were closed down or transferred to Marconi Defence Systems Limited, leaving only the Neutron Division (later called Applied Physics Division) and the Mobile Radar Division (MRD) and Sonar Systems Division (SSD) at Welwyn Garden City, reporting to GEC Avionics at Rochester. In 1988 Mobile Radar Division was transferred to Aviation Service and Repair Division (AS&RD) at Rochester and in 1990 Sonar Systems Division was transferred to Marconi Underwater Systems Limited.

In view of the complexity of the Company's structure and the wide scope of its business, the history of product development since 1958 is probably best treated by groups of products. Usually, these will have been associated directly with a similarly-named Division.

9. Military Aircraft Automatic Flight Control Systems

In 1958 work was started at Borehamwood on a new automatic flight control system for the English Electric TSR2, a high-performance aircraft for use both for strike and reconnaissance purposes, with airborne electronic equipment of a new order of complexity compared with earlier RAF aircraft. With the formation of Aircraft Controls Division, a separate section was established to act as a project team for this development, which continued to expand as the project proceeded and eventually became the major part of the engineering team in Military Aircraft Controls Division. The complete system of automatic control equipment, hydraulic power controls, simulated control surface forces, and simulated characteristics was assembled at Rochester in a special test area, and extensive proof testing was in hand throughout 1963. For flight trial purposes a data link was established, from the Flight Test Centre, to relay the results of measurements directly from the aircraft to a recording centre at Rochester, so that minimal delays would be occasioned in predicting adjustments to the system to improve the performance. As is well known, the entire TSR2 project was abruptly cancelled in 1965 shortly after the first flight of the aircraft, at a time when engineering effort was only a little past its peak, and pre-production preparation was in a period of intensive activity. It was greatly to the credit of the Company that its was resilient enough to cope with a major cancellation of this nature. In spite of the large number of people engaged on the project at the time, only a handful had to be declared redundant. There was some loss of valuable technical staff who chose this moment to leave the Company, but the vast majority of people were redeployed on to alternative work largely in pursuit of new US programmes. The size of the Division was greatly reduced almost overnight.

Before the debacle of the TSR2 cancellation, work had been started on the development of autostabiliser equipment for vertical take-off aircraft, which were then being studied by Hawker-Siddeley Aviation. The reliability required for safe hovering flight in this type of aircraft is extremely high, and the control problems are very different from those of conventional aircraft. This work led to the provision of equipment for the HSA 'P. 1127', of which a small batch of aircraft were built, and later for the RAF squadron-service version of the aircraft, the Harrier'.

Some of the effort which had become surplus in Military Aircraft Controls Division was taken up in the manufacture of flight control equipment under licence from the (USA) General Electric Company, for installation in McDonnell 'Phantom' aircraft ordered for service in the RAF and RN.

A further extension of the automatic flight control field was to the Company's first venture in the development of a system for a helicopter, the Westland 'WG 13'.

MACD was merged with TACD to form FCD in 1970 and then followed a period of intense activity in winning the prime contract for development of the Command Stability Augmentation System (CSAS) and Autopilot/Flight Direction System (AFDS) for Tornado with Bodenseewerk Geratetechnick GmbH (BGT) and Aeritalia CEA as subcontractors. Later the Spin Prevention and Incidence Limiting System (SPILS) was developed for the RAF aircraft.

Towards the end of the decade the Tornado production programme built up to become the principal production product of CACD. In 1980 the first rig equipment was delivered for the Jaguar Fly By Wire (FBW) demonstrator, which programme was to be an important foundation for future systems in British Aerospace which had less background than GEC-Marconi at the time.

20 October 1981 marked the first flight of the FBW Jaguar which was later to be modified to an unstable configuration to demonstrate the capability of the FBW system in a series of 96 flights. In this year, also the first CAD equipment was installed in ISD and CACD. This was to play a major part in winning and performing major contracts in the following years.

CACD was selected to provide the FBW system for the projected BAC PI 10 and also the Flight Control System for the Italian/Brazilian AMX.

The P110 eventually became the joint UK, FRG, Italy, Experimental Aircraft Programme (EAP) on which work commenced in 1984. In this year also the AMX flew for the first time and CACD became involved in Long Range Stand Off Missile (LRSOM) studies with Boeing and MBB.

First deliveries of EAP hardware for rig work were made in 1985, at the end of which year the German and Italian Governments withdrew from the programme. First flight of EAP took place on 8 August 1986.

In this year also the division won a contract from McDonnell Douglas from the T45 yaw damper and AMX production began.

The next year CACD in association with Lear Astronics (which had been purchased from the Lear Co in 1987) won a share of the Flight Control System for the Lockheed, GD, Boeing YF22A fighter aircraft. Work also commenced on a one lane design of the triple redundant FCS for the Boeing 7J7 under the direction of Flight Controls Division.

In 1988 CACD delivered the 1000th Tornado CSAS which was marked by a Tornado fly past and was accepted by General Glilzow of the German Air Force on behalf of PANAVIA. Bidding commenced for EFA equipment, the ATF stick and TRN/TF additions to Tornado. Work continued on T45 Yaw Damper developments. NASA awarded CACD a contract for VSTOL controls development.

In 1990 CACD was selected for the EFA FCS leading a consortium of BGT, CESELSA and Alenia (formerly Aeritalia). The SPARTAN TRN/TF system was selected for the Tornado MLU and the YF22 Vehicle Management System (VMS) entered flight test.

10. Unmanned Aircraft

In the 1940's the Aviation Division of Elliott Bros (London) Ltd was contracted to make a production version of the flight control system for the JINDIVIK target aircraft designed by the Australian Ministry of Defence in association with the Royal Aircraft Establishment. This was developed substantially to JINDIVICK Mk2 over the next few years and upgraded again through the 1960's and 1970's to Mk 102-B, Mkl03-A and Mk4.

Jindivik

The GEC Avionics control system in the Jindivik provides full ground control of the aircraft from engine start on the runway until it lands. The aircraft is stabilised in both pitch and roll. The autopilot provides the following modes:-

- Climb
- Level cruise
- Height lock
- Descent and approach

Drones and Unmanned Aircraft

GEC Avionics designed and manufactured the autopilot systems for the Canberra and Meteor strike aircraft when they were converted to the remotely piloted target role.
Universal Drone Pack To enable manned aircraft to be converted to RPV use (and, if need be, back to their manned role), a special autocontrol package was developed. This package, (sometimes referred to as an "iron-pilot") was interchanged with the ejection seat and fitted onto the seat rails. The host aircraft then needed the minimum modification to wiring and hydraulics. The Sea Vixen employed this system, and this work was carried out in close cooperation with Flight Refuelling Ltd., who were responsible for the aircraft conversion.

Rushton Sea-Skimming target

Another project in which GEC Avionics worked closely with Flight Refuelling Limited was the Rushton towed target system. GEC Avionics produced the flight control computer which, together with a Plessey radio altimeter, was used to guide the target in accurate sea skimming flight (3 feet at between 17 feet and 500 feet) at up to 400 knots.

Falconet

The Falconet system was designed to minimise target cost. This philosophy dictated the provision of the simplest "on board" system consistent with ease of control in manual modes and adequate target stability in all proposed roles. It was possible to achieve this aim by supplementing the airborne hardware with a flexible ground-based command control unit with a microcomputer interface between the operator and the target.

The Machan Programme

This programme, which was carried out on behalf of FCD by the Flight Automation Research Laboratory (another division of GEC Avionics at Rochester) embraced the provision of an unmanned aircraft flight research facility. This programme provided an experimental payload carrier which was used in a flight trials programme both by GEC Avionics and the UK MoD who, with the company, funded the programme.

Total responsibility for the aircraft, its avionics and payloads, the ground control station and conduct of the flight trials was vested in the company.

Phoenix Battlefield Surveillance RPV System

The Flight Controls Division of GEC Avionics Limited was selected by the Ministry of Defence (Procurement Executive) as prime contractor for the British Army's PHOENIX remotely-piloted surveillance system. The selection was made following a Ministry-funded competitive study which included flight trials jointly conducted by GEC Avionics Limited and Flight Refuelling Limited of Wimborne, England.

PHOENIX, the Army's first fully-equipped pilotless aircraft system for real time remote targeting and battlefield surveillance, is a small piston-engined air vehicle with advanced avionics and infra-red imaging system, an air/ground data link, a mobile ground station and logistics vehicles for launch and recovery.
As prime contractor, Flight Controls Division involved the expertise of a number of important sub-contractors, including sister companies in GEC.

Many aspects of the system's performance were demonstrated during the study phase, including trials with a full-size air vehicle and fully representative control systems. The aircraft was launched using ground equipment of pre-production standard. The infra-red sensor comprises thermal imaging common modules (TICM II) produced by GEC Avionics at Basildon. This was demonstrated in a helicopter using representative air to ground data links.

The piston engine was controlled from a digital system developed and tested in the Rochester Fuel Flow Laboratory.

11. Transport Aircraft Flight Control Systems

From the early days of the Aviation Division it had been hoped to enter the civil aircraft flight control field, in order to reduce dependence on military projects. The opportunity to take this step came with the planning of the Vickers 'VC 10' for which Elliott Brothers secured an order to provide a complete automatic flight control system. This would not have been possible without a degree of reliance on Bendix experience, and a licence was negotiated with them to make use of their latest autopilot series, the PB 20, from Eclipse-Pioneer Division.

From the outset, the 'VC 10' system was planned to make provision for fully automatic landing of the aircraft. It was realised that certification to make this permissible in airline service would be several years away, but long experience at the RAE Blind Landing Experimental Unit had demonstrated its feasibility. For certification ever to be possible an extremely high standard of reliability was essential, and even in the case of failure of the equipment it was a requirement that the aircraft must not be subjected to violent maneouvres. After a detailed study of possible alternatives, the solution chosen was to employ elaborate self-monitoring and to duplicate the whole of the major system, one half to be operative while the other was to be 'standing by', with a changeover mechanism of the utmost reliability to permit instant switching from one to another. Of equal importance was that the VC10 had fully powered controls on all surfaces which used an integration patent held by Jack Pateman. This was a brilliant solution to the problem of driving both flying control and moving the pilot’s controls in the era before Fly By Wire.

By 1960 the basic development was substantially complete and the requirements for automatic landing were being explored in detail. The first phase of this was to provide an 'autoflare' facility, by which the aircraft could be flared out automatically in pitch from its descent path, for final landing by the pilot. This was to be followed by the true 'autoland' facility, development of which was started in January 1963. In fact the autoflare was deemed to be impractical and was abandoned

Successful development of the 'VC 10' system resulted in the opportunity to supply broadly similar single system equipment for the British Aircraft Corporation 'BAC 111', which has been produced in substantial numbers. This system was more aimed at low visibility operation than for blind landing. The BAC1-11 development needs led to expansion for world-wide support and particularly in the

USA.

Early in 1963 joint proposals were made, together with Bendix, for a flight control system for a proposed supersonic civil transport. This was the forerunner of what became the 'Concorde'. The system concept proposed was a direct development of the VC10 architecture. When Anglo-French agreement was reached for joint development of the 'Concorde', a formal agreement was signed for cooperation between Elliott Brothers and Bendix although the company became the leader of the project and later acquired a further partner, the French firm SFENA. This equipment was based on contemporary semiconductor integrated microcircuits technology and may be considered to be of a different generation from the earlier systems. Preproduction equipment was used for initial test flying of the first two prototype aircraft, and further developed to production service standards between Elliott and SFENA alone.

A completely new kind of control system was required for the giant Lockheed C5A military transport aircraft, later named ‘Galaxy’. To simplify landing in the presence of a cross-wind which causes the aircraft drift, the whole of the landing gear is arranged to be rotated through the angle of drift until after touch-down. The landing wheels are then aligned with the axis of the aircraft as it rolls along the runway. To control the rotation of the landing gear a special digital computer was required which was designed and supplied by the company. The system was also used for ground steering.

In 1970 TACD was merged with MACD to become FCD and in 1973 won the contract for the Boeing YC-14 flight controls electronics.

Boeing YC14 flight controls electronics

The Boeing company manufactured two prototype YC-14 aircraft as part of the United States Air Force Advanced Medium STOL transport (AMST) Programme. This programme was directed towards modern tactical airlift and the prototype aircraft were built to demonstrate technology, performance and cost to potential.

The digital Electrical Flight Control System (EFCS) provided non-reversionary fly-by-wire control of the upper surface blown (USB) trailing edge flaps and spoilers plus fly-by-wire control, with mechanical reversion of all the remaining primary control surfaces.

The system utilised autothrottle plus modulation of the USB to control approach speed during assault landing. Level 1 hands-off no-flare touchdowns were achieved during the demonstration phase with a two-crew cockpit.

The GEC design system comprised triplex Flight Control Computers (FCC) based on 16 bit processors derived from the Tornado programme. The FCC’s operated in a frame synchronised manner utilising sensor voting selection, the data being exchanged via optical links to ensure a very high level of failure isolation.

The optical cabling interfaced via modified bayonet military connectors and was bound into the aircraft wiring using normal techniques. During over 600 flight hours achieved, no optical cables are removed or interfaces found to be faulty.

In 1979 FCD won the contract for the Slats and Flaps control system for the Airbus A300 and A310. The system was based on the earlier failure survival experience but used dissimilar redundant software controls i.e. two different computers using different software programmed by different teams of engineers, using the very highest level of fail safety control.

1980 saw the first demonstration of a fly-by-light control system developed with the assistance of the Flight Automation Research Laboratory. This was designed for the airship then being designed by Airship Industry. The programme was adopted by the US Navy in 1987 and flew in 1988 on the Airship Industry Airship 600.

The first Airbus Slat and Flap Computer was delivered for flight test in 1981 and flight tested in 1982 with production deliveries commencing in 1983.

A similar modified system was selected for the A320 in 1984 while deliveries of equipment commenced in 1986 with a first flight the following year and the aircraft entered service in 1988.

In 1986 Flight Controls Division (FCD) was selected by Boeing as one of two competitors (the other being Bendix)
As prime contractor, Flight Controls Division involved the expertise of a number of important sub-contractors, including sister companies in GEC.

Many aspects of the system's performance were demonstrated during the study phase, including trials with a full-size air vehicle and fully representative control systems. The aircraft was launched using ground equipment of pre-production standard. The infra-red sensor comprises thermal imaging common modules (TICM II) produced by GEC Avionics at Basildon. This was demonstrated in a helicopter using representative air to ground data links.

1980 saw the first demonstration of a fly by light control system developed with the assistance of the Flight Automation Research Laboratory. This was designed for the airship then being designed by Airship Industry. The programme was adopted by the US Navy in 1987 and flew in 1988.

The first Airbus Slat and Flap computer was delivered for flight test in 1981 and flight 1982 tests were continued through 1982 with production deliveries commencing in 1983.

The modified system was selected for the A320 in 1984 while deliveries of equipment commenced in 1986 with a first flight the following year and the aircraft entered service in 1988.

In 1986 Flight Controls Division (FCD) was selected by Boeing as one of two competitors (the other being Bendix) for the B7J7 Fly-By-Wire controls and development for the B777 aircraft which had emerged as the next new Boeing transport.

In July 1989 FCD was awarded the contract for the Spoilers Electronic Control Unit (SECU) for the Canadair Regional Jet and first deliveries were made in 1990.

In March 1991 FCD was awarded the contract for the production fly-by-wire system for the Boeing B777 the first US full fly-by-wire civil aircraft. The 15-year expected contract was renewed after the first decade of supply.

12. More inertial navigation

In an attempt to make use of the experience gained in designing the inertial navigator for 'Blue Steel', the Company embarked on the development of a general purpose instrument for aircraft navigation, and an experimental stable platform, E5, was built. This project was not completed, as it was realised that the platform was likely to be too bulky for many applications, and improvements in the technique appeared to offer scope for a reduction in size. This was realised in the E3 stable platform, using a novel gimbal system which permitted a very compact construction. This design entered production for the Hawker Siddeley Aviation 'Nimrod' maritime strike and reconnaissance aircraft, and is currently giving good service.

A further development of the E3 platform, the E3R, which permitted a wider range of manoeuvre, was specified for the BAC/Breguet 'Jaguar' fighter and entered production in 1970 and the Company enjoyed a long production run of this equipment.

A modified version of this E3 platform was sold to the RN and other Navies as the Naval Compass Stabiliser (NCS1).

In 1982 the Inertial Navigation (IN) Division developed the MAVHRS a heading reference system for road vehicles and in the next year negotiated a licence from Honeywell for their Laser Inertial Navigation System (LINS).

In 1984 IND merged with Gyro Division to form Guidance Systems Division (GSD) and using technology developed in FARL commenced marketing a Digital Colour Map. The first solid state miniature START Gyros began development testing.

The following year a Terrain Referenced Navigation system was demonstrated in an RAE Bedford HS748. This was followed by T^ trials in the USA. GSD also won a contract to make the IN platform for the Multi Rocket Launch System (MLRS).

In 1987 GSD won the contract for the Digital Colour Map Unit for the Harrier GR7, a development contract for Azimuth Position and Elevation System (APES) for the Warrior light tank and T^ was demonstrated both in the Tornado and A6 aircraft.

Production deliveries of APES and MLRS commenced in 1988 and demonstrations of T^ continued in UK and USA.

In order to carry out the computations necessary to display the required navigational information to the crew, Inertial Navigation Division, supplied digital computers and supporting programming facilities for this class of work.

13. Flight Instruments

The Company's experience with pressure-operated instruments can be traced back to the air data computer for the 'Lightning' automatic flight control system. A difficulty in extending the use of such designs was found during the development of new types of servo-driven panel instruments, since each one was a special-purpose electromechanical unit, involving much mechanical design work. A great step forward was made with the design of a modular kit of sub-assemblies for air data computers, which could be assembled in different combinations, in a highly versatile way, in order to meet almost any requirement. This involved interchange ability and ready interconnection of mechanical, as well as electrical, components, and represented a considerable technical achievement. This family of modular air data computers was fitted to the Nimrod Maritime Patrol aircraft, the Jaguar fighter bomber and notably to the Lockheed C5A Galaxy transport. The award of this contract in 1965 saw the beginnings of the support and manufacturing facility set up in Atlanta Georgia which later became GEC Avionics Inc.

However, the days of analogue electro-mechanical air data computers were numbered and in the 1970's ISD developed a digital computer containing a microprocessor which was flown in a number of test helicopters as LASSIE (Low Airspeed Sensing Indicator) and also employed a unique swivelling probe which allowed accurate measurement of airspeed, sideslip and rotor downwash from a single sensor.

Ultimately, this was fitted to the Bell AH1 Army helicopter with production deliveries commencing in 1979 and over 800 being delivered by 1984. Versions of this system were also fitted to the Agusta 129 and the EH 101.

Also, during the 1970's ISD, having failed to win the contract for the Tornado digital air data computer, were successful in supplying the Triplex Transducer Unit and the Stores Management System for this aircraft and also continued with PV and Government support of the development of a digital ADC.

Following a market survey of the US Navy and Air Force Logistics Departments ISD won a contract in 1981, after a severe competition, to develop a range of modular Air Data Computers to replace existing analogue systems in 37 variants of aircraft in US service. Although in a leader-follower competition with Garrett AiResearch eventually all the production contracts were awarded to GEC and production rates achieved 150 per month in 1986 and later. Further aircraft types were later added to the list for retrofit of this Standard Central Air Data Computer (SCADC) and in 1992 the deliveries exceeded 6000 units.

The main feature of this system, apart from the fact that the equipment was directly interchangeable on-line, with the analogue equipment it replaced, was the 80% commonality of modules within the four configurations which covered the whole range of 10 aircraft in 37 variants. Reliability was also guaranteed at over 1500 hours MTBF, which was over 10 times better than the replaced equipment. A number of other configurations using the same common modules was later added to the range.

In 1988 ISD won the Queen's Award for Technical Achievement with the system.

In 1988 further development of the concept produced Mini SCADC for fitment to the Canadian CF116 and Lockheed C130. This extensive background lead to ISD winning the contract for the Eurofighter Air Data System along with partners in Germany, Italy and Spain. This system which is quadruplex employs sensor vanes developed by Crouzet in France.

During this period ISD also developed a range of solid state displays employing liquid crystals which were tested in a number of experimental aircraft.

For the calibration of pressure-operated instruments the Company established a barometric standards laboratory with facilities which are of superlative quality, equalled by very few laboratories in the United Kingdom.

14. Gyroscopes

Although the Company had manufactured simple electrical feedback rate gyroscopes since 1950 based on the German Siemens WWII development and had incorporated other makers' units in several equipments, original work on gyroscopes of the highest quality did not begin until 1957 with the establishment of a small section at Borehamwood, for which key personnel had been trained at Massachusetts Institute of Technology under Dr C.S. Draper. In 1960 this section began supplying sub-miniature fluid-filled rate gyros under a sales agreement with Northrop Nortronics Corporation, and the volume of work was sufficient to justify formation of Gyro Division in 1961. This was transferred to Rochester in 1963 and began manufacture of these instruments in new 'super-clean' rooms, since when some thousands have been supplied.

The Division has applied its knowledge of airborne gyro equipment extensively to guided missile applications, for example in 'Sea Dart', 'Sea Cat' and 'Martel' air missiles, and more recently to naval torpedo applications in which the problems are of a similar nature. Aircraft for which equipment has been supplied include TSR2', 'Sea Vixen', 'Phantom' and 'Harrier'.

In 1980 first production deliveries of the Control Sensor Unit for the Sting Ray Torpedo were made and further developments took place to provide a system for Spearfish.

In 1984 the Gyro Division was merged with IN Division to form Guidance Systems Division and a new solid state gyro called START commenced development testing. This was designed for smart missile application being capable of sustaining up to 400g.

Production of the START gyro commenced in 1986 and designs as a suspension stabiliser for Formula 1 racing cars were begun. Test firings in missiles and tests in racing cars took place in 1988. In 1992 GSD won the Prince of Wales Award for Innovation with the START gyro.

15. Fuel System and Engine Instrumentation

Early experience with engine tachometers, and Bendix-type fuel flowmeters, formed the basis for Aircraft Engine Instruments Division, established in 1959. Main emphasis continued to be on fuel flow-rate sensors and associated instrumentation, using variants of the Bendix volumetric sensor which detected only an approximation to the mass rate of flow of fuel, the quantity to be measured for jet-engine operation. Equipments were supplied in large numbers for 'Victor' and 'Vulcan' bombers, 'Viscount', Vanguard', and 'BAC 111' airliners, and a number of other aircraft. In order to improve the accuracy of mass flow measurement, the Company initiated the development of a new sensor to detect true mass flow precisely and brought this to a successful conclusion with the installation in the 'VC 10'.

Design study work had been carried out on fuel contents gauge indication, but first experience in practice was gained with the acquisition of Firth Cleveland Instruments Limited, whose work in this field and in turbine-type fuel flow metering was later transferred to Rochester. Shortly afterwards, a licence was negotiated to manufacture Minneapolis-Honeywell contents gauging equipment for the Lockheed 'Hercules', and McDonnell F-4 Phantom in service with the RAF and RN.

The fuel contents gauging work largely ceased at the conclusion of deliveries for the UK F4 and C130 programmes when the division failed to win the contract for the Tornado system.

The VC10 True Mass flowmeter system was developed and fitted to the Harrier and Phantom in 1966 and through the ELDEC corporation (then called EDC) in Seattle a version was fitted to the Boeing 747 in 1970. The flowmeter contract for the Tornado was also won in 1970's but a contract was also won for the V2500 engine with production commencing in 1988. A new solid-state meter was designed and a contract for fitting to the Eurofighter obtained in 1991. This employed a novel vibrating beam to measure flowrate by the change in frequency. The main advantage was the higher reliability and lower pressure drop.

16. Digital computing

Although by 1960 Elliott Brothers had made considerable progress in the development of general-purpose digital computers for commercial use, in particular for scientific computation, none of this work had been directed towards airborne applications. In an attempt to gain a foothold in aircraft digital computation, the by now time-honoured practice of licensing an existing proven design was adopted, with an agreement to manufacture the 'Verdan' computer of Autonetics Division, North American Aviation. This was primarily intended for navigation and weapon-aiming computation in

military aircraft, notably the TSR2', and Airborne Computing Division was established at Borehamwood to handle this work.
In succession to 'Verdan' the Company developed its own range of miniaturised digital computers, the 920 Series, variants of which have been extensively applied, notably in 'Nimrod' and 'Jaguar' aircraft, and as components of display and automatic test equipments developed by other Divisions.

Current emphasis on digital techniques results in continuing demands on computer experience, and in particular on that of highly reliable and densely packed types of electronic assembly originally designed for computer use. An important aspect of design is the study of heat flow from the electrical components to prevent excessive temperature rise: this has become highly significant in spite of the low power levels of semi-conductor devices owing to the compactness of present-day designs.

17. Maritime Aircraft Systems Division (MASD)

MASD was formed in 1973 from the Airborne Computing Division (ACD). ACD was responsible for introducing computers into aircraft projects. It developed the Navigation and Tactical Systems for the Jaguar and the Nimrod MR Mkl and the Digital Waveform Generator for Head Up Displays installed in the American Corsair A-7 aircraft.

By the late sixties advances in digital technology, and their application to signal analysis, permitted an advanced acoustic processing system to be designed. The requirement called for a more comprehensive, sensitive, flexible and reliable system than was available to locate and track submarines. The challenging task of developing an improved system was contracted to GEC Avionics by the Ministry of Defence (MOD).

This new system, known as AQS 901, was required to increase significantly the anti-submarine capability of the RAF's Nimrod aircraft. Such importance was attached to the project that MoD insisted the task be given to a division devoted solely to the programme and so MASD was formed in April 1973.

The AQS 901 proved very successful in squadron service with both the Royal Air Force (Nimrod MR Mk2) and Royal Australian Air Force (P3-C Orion). It led to the development of lightweight acoustic processing systems (the AQS 902 series) and tactical processing systems for Anti-Submarine Warfare (ASW) helicopters such as the Sea King Mk5 and smaller maritime patrol aircraft such as the Atlantic and Grumman A2. The AQS 902 systems met with similar success. Development of AQS 903 commenced in 1983 and was ordered into production for EH101 in 1985.

In 1983, MASD was the first division to be awarded the Queen's Award for Technological Innovation for its successful acoustic processor developments over the past ten years.

18. Airborne Displays

Airborne Display Division was first established at Rochester in 1963 and began directing attention to conventional types of flight director instrument. In 1965 the interests of Rank Cintel Limited in this field were acquired. This company had developed a cathode-ray tube 'head-up' display system invented by the RAE at Farnborough, by which instrument data was presented to the pilot reflected in a glass screen placed in his normal line of sight and collimated to infinity first. The pilot could read his instruments, for manual flight control, navigation, or weapon-aiming purposes, without refocussing or redirecting his eyes from the scene in front of him.

After a brief association with test equipment activities, the Division was reformed, and developed a similar system using more modem techniques for supply to USA first on the ILAAS program with Sperry. This gave practice in developing complex equipment against very stringent requirements, both technically and contractually. This experience proved to be extremely valuable in handling a much larger contract for the supply of a 'Head-Up’ display system to Vought Aeronautics Division of L.T.V. Aerospace Corporation for the 'A7' naval aircraft. To secure this contract represented a major export achievement and indicated that the Company was a world leader in airborne display techniques. In addition, extremely high standards of reliability and maintainability had to be achieved to attain contractual targets, calling for a highly refined electronic, mechanical and optical design.

As a result of the demonstrated capability ADD won a contract to supply HUD's for the General Dynamics F16 which was ordered for the US Forces after intense competition between GD prototype YF16 and McDonnell Douglas YF17, later to become the F18. This was a major boost to the company since the F16 was later sold to a number of European Countries and to meet offset agreements ADD organised manufacture of the HUD in Norway and Holland. Eventually the F-16 became one of the largest production jet fighters of all time.

ADD continuously developed the HUD optics during the 1970's and in 1980 won the HUD for the LANTIRN system to be fitted in the A 10 and F16. This HUD employed new Holographic Techniques for manufacture of the HUD optics.

1982 saw delivery of the first LANTIRN prototype, the 2000th A7 and the 1000th F16 HUD. The following year a LANTIRN HUD was developed for the F16 C/D aircraft and the Falcon Building was opened at Rochester Airport Works for Holographic Production work.

Meanwhile, ADD had been developing pilot's goggles using HUD principles and in 1984 the Cat's Eyes prototype was demonstrated giving a night vision capability to the pilot. This was ordered into production by the US forces in the following year when also full LANTIRN production commenced.

In 1986 ADD won the HUD contracts for the UK Experimental aircraft Programme (EAP) and the US C17 military transport. Development of night vision goggles and helmets continued.
Successes with F16 exports and development of night attack systems with RAE lead to the receipt of Two Queens' Awards by ADD.

In 1988 ADD delivered the 1000th HUD for F16 C/D, the 1000th TV Display for Tornado and production of Holographic HUDs began.

Orders were also received for YF22 and A6 in USA and the F8 in China. The work on EAP ultimately lead to the award of the contract for the EFA HUD in 1991, leading a consortium of Teldix, Alenia and Ceselsa.

In 1993 ADD delivered the 5000th F16 to General Dynamics and manufactured the 10,000 HUD overall, the Prime Minister (Mr John Major) carrying out the formal handover.

19. Test Equipment

As already indicated, the Divisions concerned with test equipment have undergone a series of changes, basically as a result of the Company's policy from early days of making available a range of test equipment to simplify calibration and repair of its products and operating this as a business organisation.

With the increasing complexity of equipment, and the need to test systems as well as individual items, attention was turned to the development of automatic test equipment in 1961. This progressed to the state where extremely elaborate computer-controlled automatic test equipment was developed and supplied for testing the avionics units of the 'Nimrod' and the head-up display equipment supplied for the Vought 'A7' aircraft. This equipment is capable of thorough checking of the unit under test, and automatic recording both of divergences from the specified performance and the location of faults.

From the work on the Nimrod programme ATED developed a computer-controlled test set called COMPACT which employed both Digital simulation and measurement techniques. This formed the basis of a bid for the Tornado Automatic Test System (TATS) a contract for which was won in 1979 leading a consortium of British Aerospace, Selenia, Siemens and Rhode and Schwarz.

A version was also supplied to MoD for the MkII Nimrod.

Deliveries of TATS commenced in 1981 and versions of COMPACT known as and COMPACT Alpha were supplied in 1982 to support manufacture of some Tornado equipment.

The commercial ATE was developed further and ORION was launched in 1984. The following year a special 1553B tester was developed for use in commissioning the EAP which was later developed into a commercial product.

Later versions of ORION were adapted to meet the US MATE programme particularly in support of the SCADC equipment.
With the ending of the TATS programme the business was insufficient to sustain an independent division and ATED (now known as Support Equipment Systems Division SESD) was merged with LCSD which later became Product Support Division (PSD).

20. Research

In order to provide a central service to individual Divisions of the Company, an Environmental Research Laboratory was established in 1961, primarily for type-testing of newly-developed equipment. Two years later the scope of activity was widened and the title changed to Flight Automation Research Laboratory. Research work covering a wide spectrum of activities has been carried out since this time, notably in highly-reliable hydraulic actuators which led to the quadruplex actuator development for Tornado, contributions to servomechanism and precision measurement techniques, and to new types of sensor; and latterly to novel methods of high-speed digital data transmission (1553 chip design) and extremely versatile diffractive optics display methods. Maintenance of a research organisation independent of the day-to-day pressures of a manufacturing Division is seen as one method of ensuring that the Company will remain in the forefront of technological progress.

Of particular note was the development in 1983/84 of a Digital Map Display for the RAE and a Fly-By-Light control system for Airship Industry.

In 1985 an underwater stereo viewer was developed along with continuation of work on a 1553 chip set and many other innovative activities to support the various Divisions.

21. Conclusion

Looking back over the 30 years during which Elliott Flight Automation took shape, became established, and emerged as a major force in the field of aircraft automatic controls and electronic equipment, it can be seen how the acquisition of particular contracts, sometimes in themselves of no great value, have laid the foundations for future progress and major expansion. The present high reputation which the Company enjoys, both nationally and internationally, is largely due to insistence throughout its activities on the highest standards of technical competence and manufacturing quality. This alone has made it possible to achieve, in the very difficult American market, a significant success, which has received the accolade of the Queen's Award to Industry in three successive years, 1968, 1969 and 1970, the last with a double citation for both export and technological achievement. The Company looks to the future with confidence.

APPENDIX 1

Growth of Company Organisation

Key to abbreviations in family tree

Divisions

A/c C	Aircraft Controls
AC	Airborne Computing
AD	Airborne Display
AEI	Aircraft Engine Instruments
APh	Applied Physics
AS&R	Aviation Service and Repair
ATE	Automatic Test Equipment
CAC	Combat Aircraft Controls
CMS	Central Machine Shop
CQD	Central Quality Department
DAD	Data Analysis and Display
Env RL	Environment Research Laboratory
FARL	Flight Automation Research Laboratory
FC	Flight Controls
FFL	Fuel Flow Laboratory
FI	Flight Instrument
FSE	Flight Support Equipment
GD	Guidance and Display
GS	Guidance Systems
Gyro RL	Gyro Research Laboratory
IN	Inertial Navigation
IS	Instrument Systems

LCS	Logistic and Customer Support
MAC	Military Aircraft Controls
MC	Monitoring Control
MR	Mobile Radar
PS	Powerplant Systems (pre 1989)
PS	Product Support (post 1992)
PTE	Precision Test Equipment
SES	Support Equipment Systems
SS	Sonar Systems
TAC	Transport Aircraft Controls
TSRL	Technology Systems Research Lab

Companies

RC Ltd	Rank Cintel Limited
E(T) Ltd	Elliott (Treforest) Limited

Corporations

LAC	Lear Astronics Corporation
DSC	Developmental Sciences Corporation
GAv Inc	GEC A

Locations

(B)	Borehamwood
(H)	Hayes
(L)	Lewisham
(R)	Rochester
(S)	Sydenham
(T)	Treforest
(WG)	Welwyn Garden City
(W)	Wembley

APPENDIX 2

Divisional Managers

Aviation Division

(Prior to 1957, departmental heads reported directly to senior management)

1957-1958 C E Roper

1958 became AEI, AS&R, IN and AC

Aircraft Engine Instruments Division

1958-1963 A N Haskett

1963-1966 R A B Wilsher

1966-1970 CRReese

1970- merged with FID to form ISD

Fuel Flow Laboratory

1963-1966 D T Broadbent 1966 absorbed into AEID

1970-1977 Part of ISD 1977 transferred to PSD

Aviation Service and Repair Division

1958-1966 F J Shields

1966-1969 F H Bevan

1969-1975 D G Thomas

1975-1979 H D F Eagles

1979-1985 J A G Casey

1985 M O Barton

July 1990 - renamed Logistic and Customer Support Divisiion

Logistic and Customer Support Division

1990 M O Barton

1991 (Sept) F T Mackley

1992 (Mar) Renamed Product Support Division

Product Support Division

1992 (Mar) FTMackley Aircraft Controls

1958- 1960 WH Alexander 1960 became TAC and MAC

Transport Aircraft Controls

1960-1963 R W Howard

1963-1966 F H Bevan

1966-1970 W R Paterson 1970- merged with MACD to form FCD

Military Aircraft Controls

1960-1963 Air Vice-Marshal H V Satterly

1963-1967 D W Emmett

1967-1970 D I Jackson

1970 merged with TACD to form FCD

Flight Controls Division

1970-1979 D I Jackson (Moved to Borehamwood in 1982 and replaced Mariner in 1984)

1979-1982 J F Bussell

1982-1984 D G Clews

1984-1987 B G S Tucker

1987-1991 RW Dennis

1991- A D Hills

Combat Aircraft Controls Division

1979 formed from part of FCD 1979-1983 J C Spinks

1983-1984 C R Reese

1984-1987 K S Snelling

1987-1989 S R Frost

1989-1991 C W Humphris

1991- R W Dennis

Central Quality Department

1969-1991 K W Boardman

1991- J T France

Airborne Computing

1961-1965 B A Hunn

1965-1973 P B Rayner

1973- became Maritime Aircraft Systems Division

Maritime Aircraft Systems

1973-1980 P B Rayner

1980-1982 D G Clews

1982-1984 R F Wilkinson

1984-1987 L Hampson

1987-1991 A Gallagher

1991 S Wood

Gyro

1961-1984 A R Essex

August 1984 merged with IN to become GSD

Inertial Navigation Division

1958-1962 W A Fraser

1962-1963 R E R Smith

1963-1966 J W Reffen

1966-1968 P Wilson

1968-1971 R P G Collinson

1971-1978 J Finch

1978-1980 D G Clews

Sep 80-1982 D Eyers

Jan 83-Aug 84 R Ruggles

1984 merged with Gyro Division to form GSD

Guidance Systems Division

1984-1990 R Ruggles

1990 (Sept) M O Barton

1992 (July) G A Barnes (acting)

1992 (Aug) Merged with ADD to form GDD

Flight Instrument

1962-1966 H Hanbury-Brown

1966-1968 R P G Collinson

1968-1970 C J Frost

1970- merged with AEID to form ISD

Instrument Systems Division

1970-1972 C J Frost and C R Reese

1972-1979 C J Frost

1979-1983 C R Reese 1983-1987 J M Colston

1987-1991 F T Mackley

1991- K S Snelling

Airborne Display

1963-1966 KR Warren 1966 merged with FSED to form DADD reformed as ADD in 1967

1967-1970 B S WoIfe

1970-1983 A J Colwell

1983-1985 J C Spinks

1985-1987 G R Sleight

1987-1991 K S Snelling

1991-1991 C W Humphris

1991(0ct) - 1992 D G Clews (Acting)

1992(Mar) - July G R Sleight (Acting)

1992 (Jul) - M O Barton

1992 (Aug) - Merged with GSD to form GDD

Guidance and Display Division

1992 (Aug) M O Barton

1992 (Oct) G A Barnes (Acting)

Automatic Test Equipment

1961-1963 R Braithwaite

1963-1965 H Cook

1965 Merged with PTED to become FSED 1967 Reformed as
ATED

1967-1972 H R Bristow

1972-1975 C R Reese

1975-1981 J A G Luck

1981-1983 R Ruggles

1983-1990 A J Colwell

1990- renamed Support Equipment Systems Division

Support Equipment Systems Division

1990- A J Colwell

Oct 1990 - B J Beddoes

Sept 1991 - Merged with Logistic and Customer Services Division

Flight Support Equipment Division

1965-1966 H R Bristow

1966 merged with ADD to form DADD

Data Analysis and Display Division

1966-1967 H R Bristow

1967 became ADD and ATED

Precision Test Equipment

1961-1965 H R Bristow

1965 merged with ATED to form FSED

Environmental Research Laboratory

1961-1962 J Stewart

1962 absorbed into FARL

1969 transferred to CQD

Central Quality Department

1969 - 1991 K Boardman

1991 J T France

Flight Automation Research Laboratory

1961-1962 H Hanbury-Brown

1962-1966 R P G Collinson

1966-1969 S M Ellis

1969-1972 J F Bussell

1972-1990 R P G Collinson

1990 T G Hamill

1990- renamed Technology and Systems Research Laboratory

1990-1999 Kenny Deans

1999 C T Bartlett

1999 TSRL disbanded

Central Machine Shop

1965-1968 R Collins

1968-1970 A L Bakewell

1970-1977 R Collins

1977-1985 A Teers

1985 became Central Manufacturing Services

Central Manufacturing Services

1985- P J R Burrows

Powerplant Systems Division

1972-1979 Dr J F Bussell

1979-1988 I S D Stitt

1988-1989 C W Humphris

1989 P J Hewlett

1989- merged with Offshore Projects to form MCD

Monitoring and Control Division (Nailsea)

1989 P J Hewlett

1992 Merged with Instrument Systems Division

Power Conversion Systems

1984- H A Jones

Sept 1990 - became part of MCD

Recording Systems

1982-1984 L Beck

1984- D P Hooper

Sept 1990 - became part of MCD

Electronic Data Processing Department

19 -1982 M J Popay 1982-1985 G J Briley

1984 became Computing Services

Computing Services

1985- G J Briley

1992 M C Smith

Personnel Department

-1966 R Kenwright

1966-1967 M Moran

1967-1976 D R Hunter

1976-1986 E J Bradley

1986-1988 J D Ainley

1988-1991 A R Williams

1991 S J Kenny/P J Bowyer

<u>Training Department</u>

1974- G D Perry

<u>Applied Physics Division</u> (Borehamwood)

1987 D S Harris

<u>Mobile Radar Division</u> (Welwyn Garden City)

1987-1988 O'Keefe

1988 became part of ASRD

<u>Sonar Systems Division</u> (Welwyn Garden City)

1987-1990 I Fraser

1990 transferred to MUSL

<u>GEC Avionics Inc</u> (Atlanta)

1984 H Hanbury-Brown (Office)

W Hanron

W Alvarez

<u>E-AIC (Elliott-Automation Industrial Corporation)</u>

<u>Atlanta from 1984</u>

1979-1987 H D F Eagles

1987 W M Broyles

<u>Lear Astronics Corporation</u> (Santa Monica, California)

1987-1989 L La Cotti

1989-1990 H D F Eagles

1990 D. Dallob

<u>Developmental Sciences Corporation</u> (Ontario, California)

1987- G R Seamann

<u>Platform Solutions</u> Part of BAE Systems North America

-2004 Sue Wood

2004 – 2006 Michael Austill

APPENDIX 3			
	Senior Management		
	Elliott Bros (London) Ltd	Management Committee	Sir Leon Bagrit
	Elliott Automation Ltd	Chairman	Edgar O Herzfield
		Technical Director	Dr L L Ross
		Commercial Director	George Fairbanks
1958	**Guided Flight Group**	GFG	H Pasley-Tyler
			Maurice Gartside
		Tech Exec	Jack Pateman
	Elliott Flight Automation Ltd		
1962		Chairman	H Pasley-Taylor
		JMD	J E Pateman
			F J Mangeot
		Directors & JGM	W H Alexander
			W A Fraser
1965		Director & JGM	R W Howard
1967		Chairman	H Pasley-Taylor
		JMD	J E Pateman
			W H Alexander
		Directors & JGM	R W Howard
			P A Hearne
		AGM	H Hanbury-Brown
		Finance Director	F J Mangeot
1968		Chairman	Sir R Telford
		MD	J E Pateman
		AMD & CE Rochester	W H Alexander
		Finance Director	F J Mangeot
		Directors & JGM	R W Howard
			P A Hearne
			H Hanbury-Brown
		JGM (Prod)	A J Harrison

	Marconi Elliott Avionic Systems Ltd		
1969		Chairman	Dr B O'Kane
		MD	J E Pateman
		AMD & CE Rochester	W H Alexander
		AMD & CE Bwood	P F Mariner
		Finance Director	F J Mangeot
		Directors & JGM	R W Howard
			P A Hearne
			H Hanbury-Brown
		JGM (Prod)	A J Harrison
1973		Chairman	Dr B O'Kane
		MD	J E Pateman
		AMD & CE Rochester	W H Alexander
		AMD & CE Bwood	P F Mariner
		Finance Director	F J Mangeot
		Directors & JGM	R W Howard
			P A Hearne
			W R Patterson
		JGM (Dir of Manf Services)	A J Harrison
	Marconi Avionics Ltd		
1978		Chairman	Dr B O'Kane
		MD	J E Pateman
		AMD & CE Rochester	W H Alexander
		AMD & CE Bwood	P F Mariner
		Finance Director	D C Rickard
		Directors & JGM	R W Howard
			P A Hearne
			W R Patterson

1981		Chairman	Dr B O'Kane
		MD	J E Pateman
		AMD & CE Rochester	W H Alexander
		AMD & CE Bwood	P F Mariner
		Finance Director	D C Rickard
		Directors & JGM	R W Howard
			P A Hearne
			W R Patterson
		Dir of Personnel	E J Bradley
1982		Chairman	Sir R Telford
		MD	J E Pateman
		AMD & CE Rochester	W H Alexander
		AMD & CE Bwood	P F Mariner
		Finance Director	D C Rickard
		Directors & JGM	R W Howard
			P A Hearne
			W R Patterson
		Dir of Personnel	E J Bradley
	GEC Avionics Ltd		
1984		Chairman	Sir M Beetham
		MD	J E Pateman
		AMD	W H Alexander
		Finance Director	D C Rickard
		Directors & JGM	R W Howard
			P A Hearne
		CD	C C F Naylor
		AGM	D G Thomas
		Dir of Personnel	E J Bradley

1986		Chairman	Sir M Beetham
		Deputy Chairman	J E Pateman
		Finance Director	D C Rickard
		MD	W H Alexander
		Dir of Personnel	E J Bradley
		JGM	R W Howard
			P A Hearne
			D G Thomas
		Commercial Director	C C F Naylor
		Directors	I G MacBean
			R Williams
1987- Feb		Chairman	Sir M Beetham
		Deputy Chairman	Admiral Sir L Bryson
		Snr MD	W H Alexander
		Finance Director	D C Rickard
		Dir of Personnel	E J Bradley
		MD (Navigation)	P A Hearne
		MD (Dynamics)	R W Howard
		MD (Sensors)	W R Patterson
		Commercial Director	C C F Naylor
1987-89		Chairman	Sir M Beetham
		MD	R W Howard
		Finance Director	T D Venables
		Dir of Personnel	E J Bradley
		AMD	D G Clews
			C R Reese
			J C Spinks

		Production Director	J E Clover
		Marketing Director	J F Fisher
1990		Chairman	R W Howard
		Chief Exec	W H Alexander
		Finance Director	T D Venables
		Dir of Personnel	E J Bradley
		AMD	D G Clews
			J C Spinks
			G R Sleight
			C R Reese
			B G S Tucker
		Production Director	J E Clover
		Marketing Director	J F Fisher
		Commercial Director	C C F Naylor
		Technical Director	R F Wilkinson
1991		Chairman	R W Howard
		MD	B G S Tucker
		Directors	Sir M Beetham
			W H Alexander
			D C Rickard
			E A Peachey (Sec)
		Chief Exec	W H Alexander
		Finance Director	T D Venables
		Dir of Personnel	E J Bradley
		AMD	D G Clews
			J C Spinks
			G R Sleight
			C R Reese
		Production Director	J E Clover

		Marketing Director	J F Fisher
		Commercial Director	D T Reeves
		Technical Director	R F Wilkinson
1992		Chairman	R W Howard
		MD	B G S Tucker
		Directors	D C Rickard
			E A Peachey (Sec)
			B G S Tucker
		Finance Director	T D Venables
		Dir of Personnel	E J Bradley
		AMD	D G Clews
			J C Spinks
			G R Sleight
		Quality Director	C R Reese
		Production Director	J E Clover
		Marketing Director	J F Fisher
		Commercial Director	D T Reeves
		Technical Director	R F Wilkinson
		General Manager	R Eves
1992 (June)		Chairman	P A Hearne
		MD	B G S Tucker
		Directors	D C Rickard
			E A Peachey (Sec)
			B G S Tucker
		Finance Director	T D Venables
		Dir of Personnel	E J Bradley
		AMD	D G Clews

			J M Colston
			G R Sleight
		Quality Director	C R Reese
		Production Director	J E Clover
		Marketing Director	J F Fisher
		Commercial Director	D T Reeves
		Technical Director	R F Wilkinson
		General Manager	R Eves

