Apart from specialised component work the Marconi Company did not operate in the space sector of satellite communication and research work was therefore confined to system studies and simulation activities. Moreover from 1965, when a large group of engineers transferred to the newly formed Space Division, hardware development for the ground sector passed from Baddow into the domain of the product unit, with the research team acting as sub-contractors for specialised items of equipment and for the electrical design of the antennas.

6.13 Mechanical Engineering

There are few activities in electronics research which do not have a significant mechanical content and although its design may in some cases be within the capability of a practical electronics designer there are others, such as the development of large antennas, where a high degree of mechanical competence is required. Under both Kemp and Eastwood R.A. Nightingale led a mechanical design team, supported by Drawing Office facilities provided centrally from the Marconi Company headquarters, which provided the necessary expertise to other research workers and undertook the design of structures such as antennas and rotating mounts for those projects where the laboratories developed prototypes. This team operated within the Great Baddow Laboratories until 1961 when it was decided that it should move to Writtle and come under the control of a newly appointed Mechanical Engineering Director (G.W.F. Adler). Its terms of reference (and its strength in people) were expanded to include the provision of expert services in stress analysis, heat transfer, servo-mechanisms, fluidics and any other activity where the reliability of a product was influenced by mechanical considerations.

In most of the projects previously described, and in those which were to develop later, this team provided supporting services including, as necessary, the design of small mechanisms which were primarily mechanical in nature, such as "tracker balls" for controlling the movement of a strobe on a radar display and precision encoders where angular movement was translated into a digital code via an optically encoded disc.

In 1958 Adler took up a new appointment as Manager of the Mechanical Products Division at Felling which designed and made antennas and other mechanical components for the Radar and Communications Divisions of the Marconi Company, and the mechanical engineering team at Writtle again became part of the Research Laboratories.

7. THE EARLY 1960's

7.1 Waveguide Communication

In 1960 research work began on transmission of electromagnetic waves in over-moded waveguides, i.e. in a waveguide much larger than was necessary in order to support the fundamental mode.

An H_{01} mode in a circular waveguide is transmitted with very low attenuation providing that conversion to other more lossy modes can be avoided. This was achieved by making the waveguide from a closely wound helix in a dielectric supporting medium, thereby inhibiting the longitudinal current flow in the walls associated with higher order modes, and by avoiding bends as far as was practicable. The waveguide was obtained from another company (British Telecommunications Research - subsequently part of the Plessey Company) and the research programme carried out in collaboration with them.

Such a system using a waveguide about 6 cms in diameter and carrying an electromagnetic wave in a frequency band about 30 GHz is capable of carrying very wide band information, e.g. many television channels, and the systems research work was therefore accompanied by studies of potential millimetric wave sources and detectors. Oscillators centred on approximately 40 and 80 GHz were constructed in a microwave laboratory led by M.J.B. Scanlan and components from external sources were procured for evaluation. However, the first systems use was in an experimental X-Band radar at ASWE, Funtington in which the antenna was at the top of a mast, an over-moded waveguide about 6" in diameter being used for transferring the signals from the antenna to the base of the mast and vice versa. The components and measurement techniques developed at this stage of the work were to prove very valuable when in the early 1970's the Post Office and other telecommunications authorities in USA, Japan and Europe began to develop an interest in waveguide trunk transmission using digital modulation techniques.

7.2 Management Change

In 1962 Eastwood left the Research Laboratories to take up a position in the Engineering Directorate of the Marconi Company and subsequently to become Director of Research for the English Electric Company. He was succeeded as Chief of Research by G.D. Speake under whose direction many of the projects initiated in Eastwood's tenure of office were continued. One of these was a study of the accuracy of blind landing systems and of the effect of extraneous factors such as anomalous propagation and reflection of signals from buildings and aircraft. This work was carried out on an interference-free site at a disused airfield at Saling by a small team led by SAW Jolliffe, who had had previous experience in navigational aids in the late 1940's and early 1950's when he and others had worked on a VOR system. This new work was supported by the Royal Aircraft Establishment and was particularly relevant to the introduction of blind landing aids on Trident aircraft in 1959. The studies were pursued for some years and included, inter alia, investigations of the increase in accuracy expected to accrue from movement of the operating frequency of Instrument Landing Systems from the metric to the microwave band.

Towards the end of the 1960's interest in Microwave Landing Systems had increased to the extent that a study under the auspices of NIAG (NATO Industrial Advising Group) was commissioned by NATO, and carried out by an international team with Jolliffe as Chairman. Regrettably, although real advantages could be seen for the introduction of microwave systems they have not by the middle 1980's been adopted on any significant scale.

The last major radar activity initiated under Eastwood's direction was design and development for a system for the Army, subsequently sold overseas, and known as Green Ginger. It was an air-transportable equipment mounted in trailers, with back-to-back S and L band surveillance systems on a single antenna mount and a separate nodding height finder operating in C band.

7.3 Computing

The development of the transistor had made possible the use of digital computers in systems such as Fur Hat from the late 1950's. Their use as practical aids to engineers carrying out research and development work began with the installation of an English Electric DEUCE computer in January 1959. At the outset this was used almost wholly by specialist theoretical teams led by P.S. Brandon. Programs were written to enable tasks previously only capable of being performed by mathematical specialists to be undertaken directly by the engineers involved in research programs, and covered many diverse topics such as filter design, network analysis, heat transfer, structural analysis, circuit optimisation etc. The very limited DUECE was replaced in 1965 by a KDF 9, which enabled the scope for technical work to be enlarged considerably as well as providing a facility for commercial data processing.

While this work was in progress, engineers involved in radar data processing were examining the likely trends for the future. The semi-conductor laboratories were given the task of fabricating transistors for use in the high speed logic circuits which were necessary for real time data processing and by 1963 they were able to offer devices with the required performance.

A.B. Starksfield, E. Atkins and colleagues devised and constructed a processor, using an architecture formulated by B. Partridge and D. Jefferies, which emerged as an experimental model in 1964 when it was probably the fastest machine available in Europe and possibly in the world. It was affectionately called IMP by its designers (not because of any idiosyncrasies in its behaviour!) and was soon in use in the laboratories for development of real-time data processing systems and for a number of off-line tasks such as analysis of flight trials of new radar systems. It continued to fulfill that function for some 15 years after its completion.

Following the emergence of IMP a decision was taken to set up a Computer Division of the Marconi Company with Atkins as its Manager supported by a number of the engineers who had worked with him in the research laboratories.

They had two major tasks. One was to develop, on behalf of English Electric Computers (Kidsgrove), the 4/30 computer, one of the new System 4 series which that company was intending to launch in the next two or three years. The other was to develop from IMP a range of computers, known as the MYRIAD series, which were subsequently sold for use in radar, air traffic control, road vehicle control and message switching systems.

The first transistors for these machines were fabricated in the research laboratories, but also in 1964 it became apparent that the demand for devices emerging from semi-conductor research was growing rapidly and a new Microelectronics Division was set up in a purpose built factory at Witham. Again the Senior Research Engineer, I.G. Cressell, became Manager and in this instance took with him all his team, on the understanding that future research in silicon technology would take place in the Product Division.

7.4 Line Communication

Until the early 1960's virtually all Post Office business in line communication went to a restricted group of suppliers which did not include the Marconi Company. However, in 1963 the Post Office announced that it would be opening up the market at least for some equipment and the Communications Division of Marconi decided to make an attempt to obtain some of the business in pulse code modulation, a technique which the G.P.O. intended to use in order to increase the capacity of its existing network. At the request of the Product Division the research laboratories undertook a study of the requirements and within about a year had produced tentative designs for a 24 channel pcm equipment. Once again the team leader and a group of supporting engineers transferred to a newly formed Line Communication Division, the Manager in this instance being recruited from the existing Communications Division. This team continued development of the equipment and the Division was successful in obtaining a substantially greater proportion of the first orders from the Post Office than was obtained by any of the established suppliers.

7.5 Satellite Earth Terminals

From 1959 the laboratories had been involved in a number of studies relating to the performance of satellite systems for both communication and scientific purposes. These included defence links, navigation, satellite to ship and satellite to aircraft communication. Analogue and digital methods were investigated as means of making the best use of the limited power available from the satellite. The step to design of practical hardware was taken in 1964 when the Company was approached about a requirement for three ground stations for use by the Ministry of Defence in an experimental system being launched by the USA and known as IDCSP (Interim Defence Communications Satellite Project). The Marconi Radar Division was awarded the contract in competition with a US supplier and responsibility for project management was assigned to the Research Laboratories. Design of the transmitter, based on a high power travelling wave tube, was carried out by the Transmitter Development group in the Chelmsford factory and of the receiver by the development team in Communications Division. The antenna, a 40 ft. diameter dish in an inflatable radome, the latter being purchased from the USA, was designed in the research laboratories. The project, code named SCAT, was completed in 18 months from receipt of the order to first delivery to the Ministry of Defence and the commissioning team had the satisfaction of receiving signals from the satellite a short time after its launch and before it had been acquired by the US ground station. (This first station, installed at SRDE Christchurch, was transferred to Deffard (Worcs.) when that unit became part of RSRE and with some up-dating was still in use in the mid 1980's.)

With the formation of the Line Division of the Company in 1965 W.L. Wright Chief of the Communications Group transferred from the research laboratories to become its Technical Manager and other members of the research team joined him and contributed to the design of the Ascension Island terminal for the Apollo mission and of many ground stations, including those at Goonhilly and Madeley, with antennas up to 30 metres in diameter.

7.6 Low Noise Amplifiers

In 1958 the MASER (Microwave Amplification by Stimulated Emission of Radiation) was announced by Hughes Aircraft in the USA. Because of its potential importance as a low noise amplifier of microwave signals, a research programme was started in the laboratories, with the system design being undertaken in the microwave physics team and that of the ferrite isolators necessary to make the device work in the magneto-physics laboratory. The formidable problems involved in fabricating the maser and the liquid helium cryostat in which it was required to operate were overcome and working devices demonstrated. However, the period over which it was to find application in operational systems was relatively short because similar low noise performance was achieved from other, less cumbersome systems. (A MASER, not of Marconi design, was in fact installed at the first earth satellite station in operational use by the Post Office at Goonhilly, but was later replaced by a parametric amplifier.)

Attention was next turned to parametric amplifiers and different designs for radar and communications were evolved. A design suitable for use as the input stage of a 600 MHz radar was designed for and marketted by the Radar Division. This made use of a variable capacitance (varactor) diode manufactured by Ferranti but, as will be described later (para 8.2), an interesting reversal of the role of the two companies took place some years later.

7.7 Velocity Measurement by Opto-electronics

In 1964 the laboratories were asked by a potential customer to investigate methods of measuring the linear velocity of hot strip emerging from a steel rolling mill. W. Agar, then a member of Morgan's CW radar team, suggested that an optical technique showed more promise in this application than radar, and filed a patent on a new system. Light reflected from the strip was transmitted through a grating to a detector, which converted it into an electric signal, the frequency of which depended on the spacing of the grating elements and the linear velocity of the strip. Frequency measurements could then be carried out by well established electronic processes. The validity of the technique was established in the laboratory and some trials were initiated in a working steel mill in 1966, the later experiments being carried out in association with English Electric, Stafford. Similar equipment was assembled, under a contract from the Ministry of Defence, for measurement of the muzzle velocity of shells emerging from guns and the launch velocity of rockets. Trials of this equipment were made by the Army, in the UK and in Germany, in the early 1970's.

Also in the early 1970's the UK Police Forces were seeking a replacement for the PETA speed meter (see para. 6.3) and a contract was placed by the Home Office for examination of the optical technique. A device with the required accuracy, known as OSCAR, was demonstrated to Police Forces but was not adopted by them, partly because they were reluctant to spend the time and effort involved in convincing magistrates and juries of the validity of a new technique, and partly because a very cheap form of electronic stop watch which could be used (albeit with less accuracy) by police officers in a vehicle became available at the same time.

A further application, developed in the period 1976-1980, was in the measurement of the stopping distance (or angle) of moving machinery in the event of an emergency, such as hazard to the operator. A number of these equipments, known as TINA, were sold direct from the laboratories to the Health and Safety Executive.

8. THE LATER 1960'S

8.1 1965 Re-organisation

In 1965 a major re-organisation of the Marconi Company which had a considerable effect on the structure and work programme of the laboratories took place. Reference has already been made to the formation of Line Communication Division. The remainder of the former Communications Division became Radio Division and a new unit, called Space Division, was set up to develop and market satellite ground stations. At the same time it was decided that radar development which had been absorbed into the research laboratories under Eastwood's direction would be devolved again to the Radar Division, thereby placing that in the same position as other Divisions, i.e. responsible for its own development but calling upon the central laboratories for research. Technical Managers for both Space and Radar Divisions were transferred from the research laboratories, as was the whole of the development team for radar. Microelectronics Division had already been formed as described earlier and one more Division, Automation Division, was set up with P. Way (again from the research laboratories) as Manager supported by a team largely consisting of his previous colleagues.

Thus the size, composition and terms of reference of the laboratories were considerably changed, with the main emphasis thereafter being on research and on the provision of certain specialised services, notably the electrical design of antennas, as required by Product Divisions. In this re-organisation G.D. Speake became Director of Research.

The largest laboratories in the new structure were the Radar Research Laboratory (led by Dr. G.N. Coop), the Communications Research Laboratory (Dr. G.L. Grisdale), the Autonomics Laboratory (A.B. Starksfield), the Theoretical Sciences Laboratory (P.S. Brandon) and the Mechanical Engineering Laboratory (R.A. Nightingale). The last mentioned of these was located at Guy's Farm, Writtle. An Antenna Laboratory (F.A. Dutton) continued to do development, particularly for the Radar, and Radio and Space Communication Divisions of the Company, making use of centralised measurement facilities on sites at Baddow and Rivenhall. Physics-based research was carried out in a microwave group led by Scanlan and in the ferrite group of the Marconi Specialised Components Division, with the latter being under the administration control of the Divisional Manager but responsible to the Director of Research for its research programme.

8.2 Solid-State Physics

Following the transfer of the entire semi-conductor team to the Microelectronics Division, no group devoted to solid-state research was left in the laboratories. A small team composed almost entirely from newly recruited graduates was set up under the direction of D.W.G. Byatt to study materials other than silicon, responsibility for which was in the Product Division.

New facilities had to be assembled but by 1967 work was in progress on III-V semi-conductor materials, on chalcogenide glasses and on liquid crystal displays. Alpha numeric displays in liquid crystal were designed and demonstrated with sufficient commercial interest being generated to justify the setting up in 1969 of a small manufacturing unit in the Specialised Components Division of Marconi Communications Systems Limited.

Over a period of several years many displays were made in the research laboratory against specific requirements, often from the Ministry of Defence but also for Marconi Divisions and for civil customers. A particular strength was built up in high intensity light emitting diodes arranged in configurations to meet an operational need, a good example being the display of data from a runway approach radar in an airfield control tower where the ambient light level is often very high. A prototype system was installed at Gatwick Airport in 1972 and was the subject of much praise from the air traffic controllers but, in view of the success of the direct view storage tube (described in 6.1) in a similar role, the Radar Division decided not to undertake quantity manufacture.

Reference was made in 7.6 to research work on parametric amplifiers. This made use of variable capacitance diodes purchased from other companies but in 1978 the laboratories were invited by the Services Electronic Research Laboratories at Baldock to take on design and manufacture of a gallium arsenide diode to work at X-band, and thereby to make themselves self-sufficient in design of parametric amplifiers for the upper regions of the microwave spectrum. The work was undertaken in the new laboratory and diodes to the required specification produced within about a year of work starting. Attention was then turned to an improved design also emanating from Baldock and the team successfully completed development against a Ministry of Defence (CVD) order. Devices to this very demanding specification are still being made in the laboratories in 1985 and sold to Ferranti for incorporation in parametric amplifiers to meet operational needs of the RAF.

Two other new units were set up following the re-organisation of 1965.

8.3 The MAT Laboratory

The first was the Microcircuit Assembly Techniques Laboratory. Its initial purpose was to carry out research into interconnection techniques appropriate to the microelectronic packages which were now becoming commonplace in electronic circuitry. Amongst the techniques studied were printed circuit boards, "thin" evaporated films and "thick" printed films, soldering, welding and electro-deposition.

Using the expertise developed as a result of the research programme it was also able to offer a service to the Marconi Systems Companies on the diagnosis of causes of failure in semi-conductor components.

Owen Joseph, who had been a member of the semi-conductor research team in the early 1960's and became a product manager in the Microelectronics Division when it was formed at Witham, returned to Baddow in 1970 and under his guidance the MAT Laboratory expanded rapidly to meet a demand from the Systems Companies. The prototype devices, made initally to study a process, were embodied in new designs and the unit facilities and staff were increased to meet the specialised needs of the product divisions. By the middle of the 1970's the MAT Laboratory had established itself as a composite research, development and manufacturing facility, with the quality standards required for military or civil equipment, and was supplying a wide range of complex devices to product companies in the GEC Marconi group on competitive terms. At the same time the results of research were fed to the companies for use in their own manufacturing units, and general advice and assistance was given to those in the process of setting up new ones.

8.4 CTEREU

The second new unit was the Central Test Equipment Research and Engineering Unit (CTEREU). This was orientated towards production and took as an initial objective the formulation of test procedures and the design of automatic test equipment, with the aim in both cases of reducing the time and cost involved in the various stages of production test. Two equipments for auto testing in the factory were designed but this activity was then terminated as equipment became available from the test gear suppliers. The unit also did an intensive study of the factors which determine the cost and time involved in testing and of the improvements which might be made by better attention to equipment design procedures. This work, partially supported by the Ministry of Defence, which had became very conscious of the costs involved in designing its own equipment, resulted in a report in several volumes which was widely sold to customers in the U.K. and from overseas. When its initial purpose was fulfilled this unit became the Quality and Test Gear maintenance unit of the laboratories.

8.5 Seawolf

At the same time as the re-organisation was taking place the Royal Navy was studying the defence of its ships against missile attack and, via the Admiralty Surface Weapons Establishment, decided to place a contract for a feasibility study for a radar system specifically tailored to this application. The contract was awarded to the Marconi Company, with the Research Laboratories leading and deriving support from the Radar Division. The solution proposed was a back-to-back L band/S band surveillance system and an X-band differential tracker, with a separate C band command link to the intercepting missile, which was being studied under a separate feasibility contract placed with British Aerospace. Stage A models for this equipment were developed in the late 1960's by the Research Laboratories while the responsibility for full development and manufacture passed to the Radar Division. In the event modifications in ship design demanded a reduction in overall weight. New versions of the equipment were therefore offered and sold by the Radar Division (now become Marconi Radar Systems Limited) in the 1970's with assistance, particularly in antenna design, being provided by the Research Laboratories as requested.

8.6 Martel

In 1967 another major feasibility study was undertaken by the laboratories, but this time with Closed Circuit Television Division (later to become Electro Optical Systems Division). This was for a television system to be included in an air launched missile, again being developed by British Aerospace. Transmission of the television picture from the missile to the controlling aircraft and of control signals back to the missile were made by microwave link. As with Seawolf, project management during the feasibility phase was with the laboratories and passed to the Product Division as the contract moved into development.

Apart from these two major projects the main emphasis of the laboratories after the 1965 merger was in the study of new technologies, techniques and processes in all areas of Marconi business and in the support of the Product Divisions in specialist areas. Support from Government agencies such as Ministry of Defence, Department of Industry and Home Office or from other sponsoring bodies such as the European Space Agency was sought wherever the work involved was consistent with overall Company objectives. Thus funding for the laboratories' programme was shared between the Product Companies' research contributions, their payments for work carried out against specific requests and contracts placed by outside organisations, with the first amounting to about a quarter of the total in most years.

8.7 Early Contacts with Essex University

An interesting collaborative activity began soon after the founding of Essex University in 1965. A programme of work was initiated by the Professor of Physics (Alan Gibson, a member of the staff of the Royal Radar Establishment prior to his appointment to the Essex Chair) on the infra-red equivalents of microwave components. A research student from Baddow (P. Auton) undertook much of the work, with the practical content being carried out in the Company's laboratories, and was duly awarded his Ph.D having successfully designed circulators and other microwave equivalents.

This excursion into the infra-red region of the spectrum was one of several taking place in the laboratories in the latter half of the 1960's. Using devices made in the Microelectronics Division of the Company line-of-sight communication links were assembled and voice and data transmitted over them. Attention was also turned to the laser, which had been announced by Hughes in 1958, and prototype gas lasers were made in the laboratory until such time as they became commercially available. The initial motivation for this work was the possibility of use of lasers in very wide band communication but it soon became apparent that there were possible military and commercial uses of very high power devices, and that low power systems could find application in signal processing and in holography. This work was to become particularly important in the 1970's as expertise grew and commercial applications were devised.

8.8 Project Mallard

In 1967 the Marconi Company was one of four in the UK (the others being GEC, Plessey and STC) which took part in a major study of a battlefield communications system, which was to be largely digital in its implementation and would offer network facilities to commanders in the field on a basis not previously achievable. The United States, Canada and Australia also participated with the objective of making the systems used by the Armed Forces of those nations wholly compatible.

W.L. Wright moved from the Space Division to Fort Monmouth in the USA to become one of the senior members of the co-ordinating team. The Research Laboratories at Baddow, primarily in the group led by P.N. Sargeaunt, played a major part in the studies under the direction of a "UK Board" set up for the purpose. (The Board had representatives of the four companies and a Managing Director from Plessey.)

Project Mallard was very advanced in technology but even more so as a concept in international collaboration. In 1969 the four nation agreement broke down and the UK proceeded on a more limited system (Ptarmigan) in which Plessey was destined to play the major role.

8.9 The GEC - English Electric Merger

In 1968 Speake left the laboratories to take up an appointment as General Manager, Telecommunications in the Marconi Company Headquarters and P.S. Brandon became the new Manager at Baddow. A more dramatic development in the same year was the merger of the General Electric and English Valve Companies, which brought the two previously competing research laboratories at Wembley and Baddow into partnership, although the latter still remained under the control of the Marconi Company. It transpired that the area of direct competition between the two laboratories was relatively small but steps were introduced to ensure that results of research work were from that time shared, unless the interests of GEC Companies sponsoring specific work programmes demanded otherwise.

Brandon, who had previously managed the Theoretical Sciences area of the laboratories, was particularly interested in the use of computers and had played a major part in the introduction of the English Electric KDF 9 computer to replace the now out dated DEUCE in 1966. By 1970 this had been supplemented by the still more powerful 4/70 and the range of tasks which could now be carried out covered virtually all areas of the laboratories' activities, as well as the Marconi Company's commercial data processing needs. The laboratories had also been equipped with a Real Time Computer Bureau, using Marconi Myriad machines, which was used for software development and proving and for a number of other tasks such as antenna development where real time processing was demanded.

New applications of the computer were regularly investigated, one of considerable topical interest at the time being the recognition of hand written characters. (The Post Office had had a programme of research for some years aimed at automatic recognition of postcodes but no technique sufficiently reliable to be put into operation had emerged.) The technique studied at Baddow involved recognition of features of individual letters (starts, stops, angles, curves) and it was hoped that the recognition process could thereby be made independent of the writer. In many cases indentification of hand written characters was achieved correctly or with success rates well over 90%, but again the process was not sufficiently reliable to be used in a commercial system and since machines for recognition of printed characters were then beginning to become available, continuation of research aimed at meeting the very difficult requirement for hand written material was not thought to be justifiable.

A more successful new use of the computer was in the placing and interconnection of components on printed circuit boards. A number of programs were written as part of the research activity and were widely used both in the laboratories and by Product Divisions.

8.10 Fluidics

The much wider use of electronic logic brought about by advances in semi-conductor technology encouraged thoughts on alternative forms and in particular on fluidic logic for use, for example, in mechanical systems where longer time constants than applied to electronic systems could be permitted and where explosion hazards made it desirable to avoid electrical circuits. Devices of several types were developed in a research programme carried out in the Mechanical Engineering Laboratory at Writtle and practical control systems demonstrated. Similar programmes of work were in progress in other companies over the same period but the benefits of fluidic logic relative to what could be achieved by electronic systems were not such as to encourage its application widely.

9. THE 1970's

9.1 Management

In October 1970 another change took place in the management of the laboratory. Brandon left to take up a Chair of Electrical Engineering at Cambridge University and Speake, now Technical Director of the Marconi Group of Companies, returned to Baddow to act also as Director of the Laboratory.

9.2 Vehicle Location

In 1969 the laboratories took over some exploratory work on road vehicle location which had been started in the Automation Division. (This Division was disbanded and the staff redeployed after the merger of GEC and English Electric.) The first potential application was to public service vehicles on fixed routes where it was relatively straightforward to ascertain position by revolution counting of the vehicle's wheels, since the starting point and route are known in advance. A model of the London Transport No. 11 bus route was built into the laboratories' Myriad computer and the factors causing queuing of a line of buses with long waiting gaps, a well known characteristic of that route, were clearly demonstrated. The model was also used for experimental work to establish, without having to run buses, what palliatives could be achieved by such measures as transferring passengers from one bus to another and reversing the empty one to fill gaps in the opposite direction service. A contract was received from London Transport to set up a control centre connected by radio link to a number of buses, each of which was equipped with the necessary revolution counting equipment and an encoding device to transfer its output on to the link. The Myriad computer in the control centre then calculated the positions of all the buses equipped and displayed them on a VDU. This prototype system was operated for some years while London Transport evaluated the operational benefits to be derived from a continuous picture of bus positions.

Following this work, an alternative system was devised and installed for the Bristol Bus Company by the Autonomics Laboratory, management of which had been taken over by R.P. Shipway, who had returned to Baddow after a period at the Chelmsford headquarters as Technical Director of the Electronics Group of Marconi Companies. The operators were unwilling to have a system which would give false positional information if a bus had to divert temporarily from its normal route, for example, as a result of road works. This was avoided in the new system as follows; an optical beam from a gas laser mounted in the bus was caused to scan vertically by a moving mirror. At intervals on the road coded reflecting plates were mounted on roadside poles and the relevant code transmitted by radio link from the bus back to the control centre, together with the identification of the vehicle involved, whenever the laser beam passed over the code plate. Over 2000 coded plates were installed on nine routes in Bristol City Centre and the system was assessed over a period of several months for potential operational benefits. During the evaluation exercise the General Manager of the bus company left and the incumbent decided that further investment would be devoted to improvement of the serviceability of the buses rather than to their control en route. (Our experience during the trials with bus availability tended to confirm his view!)

The next system evaluated, known as LANDFALL, was based on a patent taken out by R.D. Tyler and L. De Tullio. The vehicle to be located was no longer constrained to follow a fixed route but was assumed to operate on known roads i.e. did not make cross-country excursions from established routes. Distance travelled was measured as previously by wheel revolution counting but at each road junction the angle through which the vehicle turned was computed with the aid of a relatively simple gyroscope mounted in its boot. The co-ordinates of all junctions on the map and the angles at which exit roads emerged from them were stored in the memory of a computer built into the vehicle so that, providing the point of origin was known, the position of the vehicle could be calculated at each junction and, by wheel revolution counting, at each point in between. The position was stored in the computer and transmitted in digital code to a central computer over radio link as demanded by the computer. Thus it was possible in principle to track many vehicles. A prototype of this system, developed with partial funding from Department of Industry, and implemented by GEC Traffic Automation Ltd with assistance from the design team at Baddow, was installed for evaluation by the Metropolitan Police in London in 1978. However, it was not universally popular with the users (not all of whom wished their position to be known at all times by the Control Room!) and the benefits of full-scale installation were not regarded as sufficient to justify the costs involved. (A number of alternative systems based on position finding by radio were investigated in other parts of the world at the same time and similar conclusions on operational benefit vs. installation cost seem to have been drawn. The Plessey Company announced a system with features very similar to LANDFALL in 1986.)

9.3 The MADE Project

In 1973, following a private venture study begun in 1971, the laboratories were awarded a substantial contract from the Home Office for a system to evaluate the benefits to police forces of being able to transfer much more information from their patrol vehicles to headquarters and vice versa. This was known as MADE (an acronym for Mobile Automatic Data Equipment). Automatic determination of vehicle position was not attempted but earlier research work on a Touch-Map, i.e. a map from which coded information on position could be obtained by touching the appropriate point on the map, was exploited. This device together with two types of keyboard for data input, an alpha numeric display and teleprinter were all installed in the vehicle. Digital messages and voice were transmitted in either direction by VHF radio link. This system was evaluated by a team drawn from three Police Forces in the Midlands but, although some of the facilities were assessed as being of considerable value, only the voice radios are as yet widely applied (1986).

9.4 Wideband Communications

From its earliest days the Marconi Company has developed new business as a direct consequence of successful research and resourceful exploitation of it. Inevitably not all projects were immediately successful, but often work abandoned due to technical problems has been re-started because new techniques enabling the problems to be solved have become available. This was the case when in 1970 work on over-moded circular waveguide, discontinued in the 1950's, was revived in order to meet a potential demand by the British Post Office for new, very high bandwidth trunk systems. Technological advances in digital modulation systems using solid-state devices had made the evolution of an operational system practicable although the design of the waveguide itself, i.e. a wire helix set in dielectric was very similar to that devised over a decade earlier. The Research Laboratories were awarded a contract for the terminal equipment for use with a waveguide system initially to operate in the 30 - 50 GHz band but potentially capable of extension up to 100 GHz. This involved the design of digital modems and of a range of microwave elements to the very precise tolerances demanded of a system working at such high frequencies (i.e. wavelengths substantially less than 1 cm). By 1973 a prototype system had been installed between the Post Office Research Establishment at Martlesham Heath and Wickham Market (about 15 kms) and operated so successfully that an order was placed in 1977 with Marconi Communications Systems for the first trunk link between Reading and Bristol. However, in the meantime rapid advances had been made by various laboratories, including GEC Hirst Research Centre, in the design of low loss glass fibres for optical transmission and it appeared likely (as proved to be the case) that the attenuation through such fibres could be so reduced that this technology would overtake over-moded waveguide for wideband systems in trunk routes in the next two or three years. The Post Office decided not to proceed with any operational waveguide systems and the order for the Bristol/Reading link was withdrawn.

9.5 Fibre Optics

The stimulus for work on fibre optics had come from the announcement in 1970 by Corning of the USA of a fibre with what was at that time a very low attenuation of about 4 dB/km. The potential use of such fibres in trunk communication systems, especially if further improvements in transmission characteristic could be achieved, was considerable and research programmes on development of improved fibres and on digital transmission systems making use of them were initiated at Hirst Research Centre. At Baddow applications involving transmission of analogue signals, e.g. video from an outside broadcast television camera to a control room or to a number of users in a video conference system, could be foreseen and research work on the techniques involved was taken to the stage of prototype system demonstration both in the laboratories and, in the case of video conferencing, at the customer's (British Telecom) site. Initial work was on transmission of a single channel per fibre but by the early 1980's two forms of multiplexing were being studied: (i) electronic multiplexing on to the optical carrier and (ii) wavelength division multiplexing of the optical signals on to the fibre.

Within the Flight Automation Research Laboratory of Marconi Avionics at Rochester the use of optical fibres as a means of transmitting digital signals round an aircraft and thereby obviating the detrimental effects on equipment performance caused by pick-up of interfering signals on metallic conductors was being studied. At Baddow, miniaturised hybrid circuits were devised for use as input and output circuits for the transmission system and prototype devices were assembled in the Microcircuit Assembly Techniques Facility.