ENGINEERING

at Rutherford Appleton Laboratory

Reprinted from "Rutherford Appleton Laboratory 1985"

Alvey Programme

The Alvey programme was launched to mobilise UK technical strengths in Information Technology in order to improve the UK competitive position in world markets. It is a pre-competitive research programme between Government, Industry and academe. The programme is managed by the Alvey Directorate in London and consists of four enabling technologies, Very-Large-Scale Integration (VLSI), Software Engineering (SE), Intelligent Knowledge-Based Systems (IKBS) and the Man-Machine Interface (MMI). Directors and their staff coordinate the activities in each area. To provide computing facilities for SE, IKBS and MMI, an Alvey software/hardware infrastructure has been assembled consisting of multi-user and single-user systems networked with standard software and RAL is concerned with coordination and support. Regular mailshots of trip reports, news, announcements and research reports are made to the community in each area. Workshops, coordination of research activities, advice on grant proposals all help keep the community informed of major activities within and outside the programme. Other Alvey activities at RAL are referred to below, under the headings Pattern Recognition (MMI), and Semiconductor Modelling and Lithography (VLSI).

Software Engineering

Theorem Provers

These software tools aid the process of proving theorems and a major activity this year has been the mounting of a number of theorem prover systems for the user community. In this context, the concern is primarily with proving theorems about programs (for example, that a particular program possesses a particular property). Three current systems, ML/LCF, IOTA and Boyer-Moore have been acquired. ML/LCF was mounted on a VAX and the Atlas 10 under UTS. IOTA is a modular programming system built in Japan which includes a significant verification capability. As IOTA is written in an ancient dialect of LISP, a significant amount of work has had to be done and is still needed before it can be made generally available. RAL is the UK distribution agent for the Boyer-Moore theorem prover.

Formal Specification of Graphics

Alvey and SERC grants have been awarded for work on various aspects of the formal specification of computer graphics systems. As graphical input and output are only approximations to what is defined, proving properties of graphical systems is considerably more difficult than for conventional systems. Parts of the Graphical Kernel System (GKS) standard have been taken and expressed in formal terms (Fig 2.1) and assertions in the standards document have been rigorously analysed. The work has been done in close conjunction with ISO standards activities and has made significant improvements to the formal wording of the standard.

Intelligent Knowledge-Based Systems

Recognising the UK lead in Logic Programming, a major activity has been the creation of a special

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mk_DC_Fill_Area(f, w, v, b, pa) ≜
let  f = ( (i, b) ↦ (cr, fi, prp, pw, ph) )
and  ndcpts = i ∪ b
and  b = (style, si, fci)
and  wr = rectangle(w_min, w_max)
in   style = PATTERN ⇒
     { (p ↦ ci) | p ∈
          wstrans(w, v, ndcpts ∩ cr ∩ wr ∩ ppts)
          ∧ (ppts ↦ ci) ∈ pattern(p, pw, ph, pa) }
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Fig 2.1 Part of the formal specification of GKS.

initiative with a series of workshops aimed at creating a single balanced programme of relevant research projects. On the software side, contracts have been placed at Edinburgh University to develop NIP, a portable Prolog compiler which can be optimised for specific systems, and at Sussex University to make POPLOG (a combined LISP/PROLOG/POP-11 environment) generally available. A research project has started in association with the Alvey IKBS Community Finance Club (Alfex). The Club is producing an Expert System for use in the financial sector and the RAL work will use the 'Knowledge Base' which the Club is producing for research into the segmentation of knowledge. This is in order to investigate the extent to which Knowledge in Expert Systems can be made easier to maintain, modify or use for different purposes.

Man-Machine Interface

A major event was the international Workshop on Window Management in April which recommended a series of activities for the near future and longer-term research themes. RAL is coordinating the activities of a number of UK manufacturers to produce a standard application interface to window managers. Work has also started in defining a standard window manager which could work in a variety of environments.

Communications

Project UNISON

UNISON is one of two high-speed networking projects funded as part of the Alvey Programme. It is a sequel to the UNIVERSE project which ended in September 1984. The UNISON collaborators currently comprise Acorn Computers Ltd, University of Cambridge Computer Laboratory, Logica UK Ltd, Loughborough University of Technology, and RAL. Generally, the objectives of the project are to investigate the provision of an integrated services high-speed digital network suitable for use in the interconnection of the next generation of information technology products. Considerable emphasis is being placed on developing a basic network service and higher level value-added services within a unified architecture, capable of supplying integrated voice, image, and more conventional distributed computing services. The research elements of the project are concentrated in two areas, novel methods for constructing the network services over the Integrated Services Digital Network (ISDN) and investigations into particular advanced applications, of interest in their own right and for test use of the network. An important decision was to base the whole network design upon use of the emerging international standards for ISDNs. An incipient version of this will be provided for the project by the Alvey High-Speed Network, itself based upon 2 Mbps terrestrial links to be supplied by British Telecom and Mercury. This basic network will provide configurable circuit switched high speed links between the participating sites. Project funding was approved during the latter part of the year. The major activities since then have been in specifying the network architecture and initiating the development of specific pieces of hardware needed to interface British Telecom's Megastream to the Cambridge Fast Ring. Preliminary work on the software systems which will be used to provide the common infrastructure for the project has begun and the installation of Megastream links to participants' sites is progressing.

Alvey Infrastructure

The multi-user interactive facilities supported for Alvey consist of 11 GEC Series 63 systems and 5 Systime 8750s (VAX 11/750 equivalents) with a UNIX service (UTS) on the IBM-compatible Atlas 10 mainframe. Support for the Series 63 systems is provided by Edinburgh Regional Computing Centre under contract, while the VAX systems and the UTS service are supported by RAL using local development systems. The infrastructure also supports SUN single-user systems (see Single-User Systems below).

GEC Series 63

The major activity this year has been establishing a UNIX service on the Series 63 systems. The standard AT&T System V version of UNIX is now installed on all systems. The connection to the wide area network was initially based on the York box front-end but upgrades from 63/30s to 63/40s have greatly improved the network access to these machines.

Systime 8750

The VAX systems are provided to allow import to and export from the Series 63 systems of software required or produced by the user base. In addition, the VAX systems provide a UNIX service based on the Berkeley 4.2 version. The intention is to move to System V UNIX when the version on the VAX stabilises and is fully supported.

UTS

During the year, the UNIX service UTS on the Atlas 10 has been established and very encouraging results have been obtained in running large programs on the system. PROLOG, FRANZLISP and ML/LCF have all been mounted. Cambridge University has run in a few minutes on the Atlas 10 proofs written in ML/LCF which would have taken all night on a VAX. The 4250 erosion printer has been used extensively from UNIX utilities such as Ditroff and Pic to produce slides, technical reports and books. The combination of UNIX with the power and peripherals of an IBM mainframe service provides a facility unique in the UK.

Interactive Computing

RAL supports the Board's computing community via the Single-User Systems programme and the Interactive Computing Facility (ICF). Both are funded through the Board's Computing Facilities Committee. The ICF service continues to be based on PRIME and GEC 4000 systems distributed around the country. Support is provided for 12 PRIME systems and six GEC 4000 systems in universities and polytechnics. In addition, nine PRIME and GEC systems are supported at RAL.

GEC 4000

Support for the GEC 4000 systems is to cease. A new version of the operating system (4.15) is in preparation, for release in mid-1986. Systems at Cranfield and Bradford closed during the year and parts of these systems were used to enhance other systems.

PRIME

All PRIME systems have been upgraded during the year with additional memory, disk capacity and processor upgrades. As a result, 40% power and 20% disk space has been added to the facility. The current plan is to continue running the PRIME system for at least the next five years with a move to running the PRIME UNIX operating system (PRIMIX) alongside the PRIMOS operating system. Benchmarking of the Beta test version of PRIMIX has taken place in conjunction with Surrey University. The major addition to PRIME software this year has been the mounting of the RAL/ICL portable GKS in conjunction with Salford University. The service continues to receive good support from site managers who provide some systems development effort as well as managing the local facility. In addition, the contract with UMIST provides a large part of the PRIME support.

Pyramid

A Pyramid Reduced Instruction Set Computer (RISC) has been purchased as a multi-user system running System V and Berkeley 4.2 UNIX together. This is being used to move existing packages from the PRIME systems in order to assess the performance of such packages under a comparable UNIX system and to ascertain how such packages are restructured to use UNIX facilities. A joint activity with Pyramid will replace the X25 connection currently based on the York box by an in-board solution based on an X25 board.

DEC10

This year saw the closure of the ICF DEC10 KL at Edinburgh. Over the nine-year life of the installation, it was the major ICF facility providing an excellent service for, in particular, Artificial Intelligence and Computer-Aided Design workers, and the Science Board's Crystal Structure Search and Retrieval Database. The DEC10 system delivered a total of 75,000 Allocation Units to interactive users (about 375,000 terminal connect hours). In a typical year, the machine supported some 60 to 70 SERC grants, corresponding to between 350 and 400 active users. Over the last two years, existing users of the DEC10 have moved to other facilities. One of the last groups to move was the ABACUS design group at Strathclyde University. This group was one of the largest user groups on the DEC10, accounting for some 15 to 20% of machine usage, and has been provided with a Systime 8750 running UNIX, the first external UNIX facility supported by ICF.

Single-User Systems

The Single-User System programme continues to provide support for high-powered workstations with an agreed set of Common Base software centrally supported. This includes FORTRAN 77 and PASCAL compilers, and NAG and GKS libraries running on top of the UNIX operating system. Wide Area Network communication is provided by the JNT Coloured Book protocols for mail, file transfer and remote log-in.

Hardware

The original hardware in the Common Base was the ICL PERQ1 machine, of which about 130 systems were installed. This was followed by an architecturally similar system, the PERQ2. Much time during the year

was spent assessing various systems in an attempt to find an alternative to add to the Common Base. About 120 manufacturers were contacted initially, ten being selected as able to supply equipment of the correct power. These suppliers received a more detailed Operational Requirement and Apollo, SUN and Whitechapel were chosen for further assessment. Systems were installed and quantitative and qualitative tests were carried out, including the porting of some large applications programs. After detailed assessment of these systems, it was decided to add the SUN2 system to the Common Base. About 50 PERQ2 and 50 SUN2 second-generation systems have been installed (Plate IX). SUN has recently introduced the SUN3 and ICL is due to release the PERQ3. Major activities this year have been a final upgrade of the PERQ1s with a larger writable control store to run the most recent version of the operating system.

Communications

Local Area Network communications on the PERQ1 have been provided by the Cambridge Ring running the Basic Block protocol. These have been less than satisfactory owing to the General Purpose Interface Bus on the PERQ1 allowing only low speed communications. With the introduction of the PERQ2 and SUN2, the preferred local area network technology is Ethernet. Currently, the SUN2 systems run proprietary protocols (TCP/IP) on the Ethernet hardware while the PERQ2 systems run standard ISO protocols. Work is proceeding to integrate the two systems to allow interworking.

Software

The ICL PERQ2 has a complete range of Common Base software available and a major activity has been to ensure it was available on the SUN2. The major omission was GKS and an assessment of the GKS system provided by SUN is under way. The SPY screen editor developed by RAL has been ported to the SUN2 so that users have the same editing environment on both systems. In addition, a set of utilities forming a graphical toolkit has been developed for the PERQ2 and is being implemented on the SUN2. These provide portable standard ways of accessing input from the mouse, performing raster operations, using pop-up menus etc. Interfaces to these utilities have been provided for FORTRAN, PASCAL and C. A number of software contracts have been let to universities to augment the basic software on the PERQ2. The University of Kent has completed a set of FORTRAN utilities including a source level debugger and an implementation of the NAG TOOLPACK, which provides facilities for documenting and tuning FORTRAN programs. Other work includes on-line documentation and specialist window environments. A contract with Edinburgh University has nearly completed a LISP implementation on the PERQ2.

Computational Modelling

RAL provides a wide range of computer software to aid the engineering research community in design. The main areas covered are finite element analysis, electromagnetic fields, semiconductor modelling and tools for interactive programs. The underlying theme of this programme is the use of computational modelling techniques to enable research workers to be more productive in engineering design. This has led to the provision of state-of-the-art interactive software systems.

Finite Element Analysis

The finite element technique is used as a tool for engineering design calculations and is also an active research subject. There are three main ways in which the Laboratory provides software for finite element analysis: firstly, by the development of specific packages, such as the 'Total Scalar Potential' package (TOSCA) for 3-D field problems, secondly, by the support and development of the Numerical Algorithms Group (NAG)/SERC Finite Element Library and, thirdly, by the purchase and support of commercial systems such as the NASA Stress Analysis package, NASTRAN. Standard commercial finite element packages provide most of the analyses required in engineering design including the areas of stress analysis and heat flow calculations. A review of the stress analysis packages is in progress so that SERC capabilities in this area are suitable for the research community but there are many calculations which cannot be performed by package systems. It is in these areas where the Finite Element Library (FELIB) has been found most useful. Currently, FELIB is being used for electromagnetic and semiconductor modelling, building design, machine tool design and fluid flow calculations. These developments have produced new software which is being included in subsequent releases in FELIB.

Semiconductor Modelling

The Laboratory is forming a team to develop better algorithms and software systems for the analysis and design of sub-micron semiconductor devices. The work is being funded under the EEC initiative in microelectronic technology and the Alvey VLSI programme. RAL is the prime contractor of the EEC collaboration and is a partner in Alvey programmes in semiconductor process and device simulation. The main aim of the EEC project is to develop more efficient and robust methods of modelling the behaviour of micron and sub-micron semiconductor

devices. It is intended that these techniques will reduce dramatically the cost of such calculations. As part of this programme, the Laboratory is leading a software project to produce a new device simulator using the algorithms developed by the other partners. As part of the Alvey programme in VLSI applications, RAL is a partner in modelling the fabrication processes of semiconductor devices and in the validation of device simulators. As a major part of these closely related programmes, the partners are to develop an integrated semiconductor modelling system to simulate device fabrication and behaviour. The Laboratory has the important role of designing and implementing the software which will include a common device/process modelling data base. At RAL, a prototype two-dimensional device simulator has been written using many of the advanced techniques of adaptive mesh generation and refinement developed in its collaborative projects. This research code is now being rewritten to provide a robust design tool for the research community.

Electromagnetics

The RAL electromagnetics packages have been updated and the solver programs now run in the IBM MVS system. The transient eddy current solver for the two-dimensional PE2D code has been greatly improved. Infinite boundaries and also anisotropic permeable materials may now be represented using the TOSCA program. An example of the use of TOSCA to predict magnetic quadrupole gradients is given in Fig 2.2. Testing the 3-D eddy current package CARMEN has continued. Comparison has been made with measurements using a benchmark experiment at the University of Bath and with results from programs which use different algorithms. Indications are that, for simple cases, the program gives reliable results. Other benchmark tests will be made and compared with results from the FELIX experimental rig at Argonne National Laboratory, USA. Further development is in hand to allow modelling of multiply-connected surfaces and also for transient and non-linear problems to be solved. Further basic research in solving 3-D time-dependent fields has been undertaken by the Laboratory in collaboration with Imperial College, London and the University of Bath.

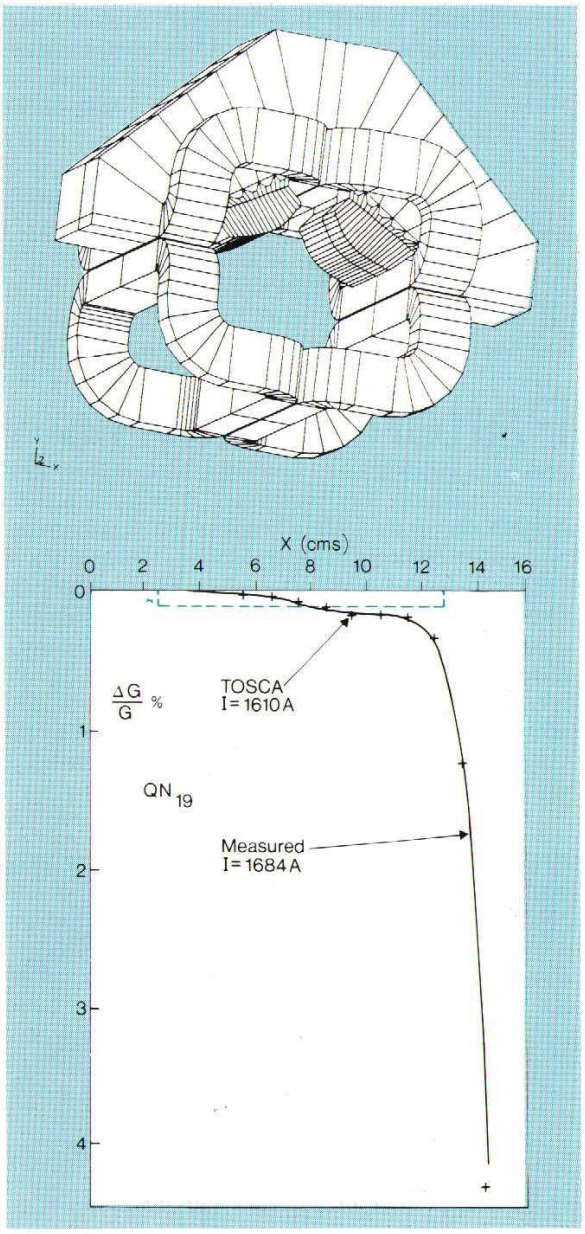


Fig 2.2 a) TOSCA computer model of the narrow quadrupole for the CERN antiproton collector. (85MB4485) b) Field gradient, integrated through the quadrupole, across its horizontal aperture. The magnet was subsequently shimmed to give a gradient constant to 1 in 10³ over the dashed region. (85MB4467)

Pre- and Post-Processing

In January, the Laboratory began active work as a partner in a further ESPRIT project on CAD Interfaces. The project, involving ten industrial and academic organisations from Belgium, Denmark, France, West Germany and the UK, is concerned with the development of software interfaces between CAD programs, finite element pre-processing, finite element analysers and experimental dynamic analysis results. Effort at RAL, in collaboration with the Belgian, Danish and German partners, has been directed towards the design of 'neutral file' structures which will allow the transmission of CAD and finite element data between different organisations and their computer hardware and software. A MEDUSA CAD workstation has been set up for use with this project and, with a modest amount of programming, a simple and convenient method has been devised for transferring complete engineering drawings to CERN making use of the Hewlett-Packard Graphics Language. The facility could be extended to any organisation with access to a suitable pen plotter. The interface between the pre-processor FEMGEN and the

finite element analysis program NASTRAN has been greatly improved for the benefit of the many engineers within SERC and universities. The task of adapting FEMGEN to run on a single-user workstation such as the ICL PERQ has commenced. In future, pre- and post-processing of finite element models will, in most cases, be performed on such workstations, analysis taking place on mainframe computers with the necessary data transfer over local area networks. Research into the subdivision of tasks between the two types of machine will be a major concern.

Pattern Analysis

Support

RAL has widened its support of research into the analysis and interpretation of sensory data such as satellite imagery, medical nuclear magnetic resonance images, pictures of industrial scenes and speech waveforms. In addition to coordinating pattern analysis activities throughout SERC, RAL staff have also assumed responsibilities for infrastructure activities of the Alvey Vision and Speech Clubs.

Computer Vision

The three-year collaborative project in computer vision involving RAL and Computer Recognition Systems Ltd has formally ended. The aim of the project was to develop robot vision systems for automatic inspection and assembly of industrial components. One of the main features of the research programme was the development of special-purpose integrated circuits for low-level image processing. Four circuits (convolver, edge detector, median filter and histogrammer) are in various stages of development and should become available in the near future. Algorithm research concentrated on aspects of shape analysis. A number of circularity measures have been experimentally studied. A new method of assessing circularity of object boundaries based on the Hough transform has been developed. The method is even suitable for inspecting incomplete circles.

Fringe Image Analysis

RAL is developing software, in collaboration with Trent Polytechnic, which will automatically locate correlation fringes in images produced by an Electronic Speckle Pattern Interferometer (ESPI). The long term purpose of the project is to create a general automatic

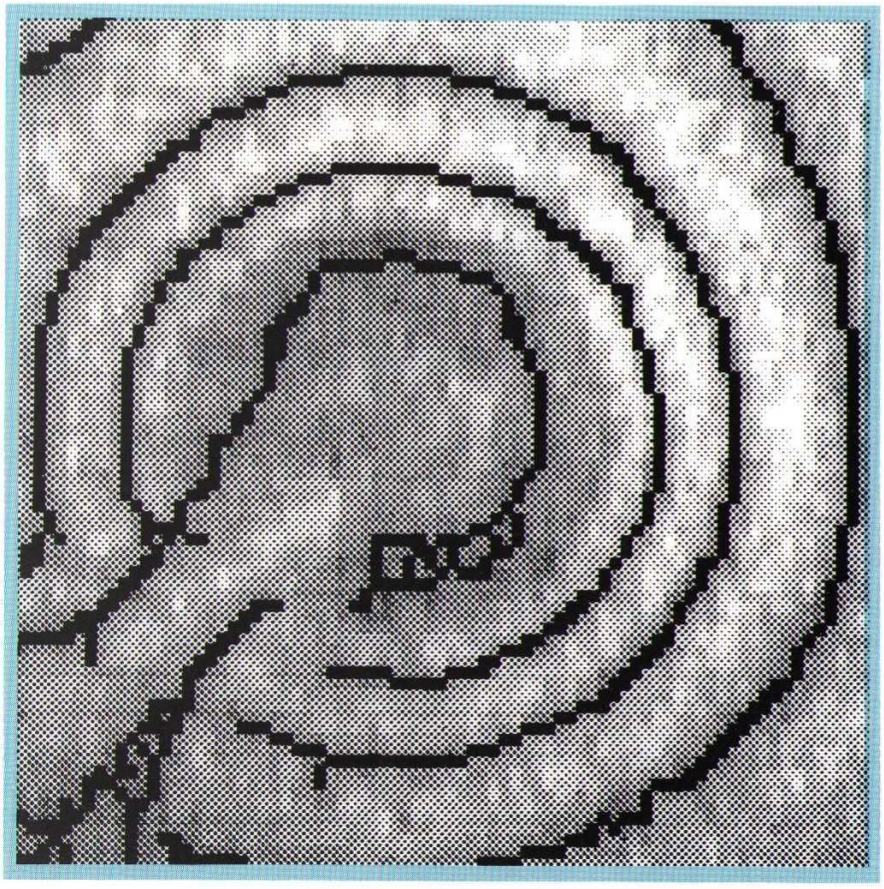


Fig 2.3 Computer-digitised interferometer image of a heat-exchanger surface. Fringe minima contours are shown in black. (Edinburgh University) (85MB4533)

fringe analysis system which will be of use in the analysis of moire, holographic and ESPI fringe images. These images are extensively produced in areas of non-destructive testing (NDT), fluid flow visualisation, metrology and thermodynamic evaluation. The particular application being considered is that of determining the heat transfer coefficients for a specific heat exchange surface using a swollen system (Fig 2.3). Subsequent evaluation of fringe separation and ordinal number will allow measurement of the optical path difference corresponding to each point in the image and the contours of the polymer surface.

Microelectronics Facilities

Computer-Aided Design of Electronic Systems

For several years, the Laboratory has provided a Computer-Aided Design (CAD) Facility to the academic community for research and post-graduate training in circuit and, in particular, integrated circuit design. The Facility is also used within the Laboratory in several areas of the Council's programme, for example, the design of four chips for a collaborative project in image processing between RAL and Computer Recognition Systems. In general, designs range from complex integrated circuits containing many tens of thousands of transistors to small projects undertaken as part of SERC-supported MSc courses at a number of universities. The CAD Facility currently serves over 300 users in more than 30 universities and polytechnics. The programme of the CAD Facility aims to collect some of the best available software to form an integrated design system running on SERC computers. This year has seen a consolidation of this design system which will enable designers to carry out more complex projects.

Cell Library

A 5μm CMOS standard cell library was licensed from Silicon Microsystems, which supplied the internal mask layout of the cells. RAL staff have added three other parts to the library: i) the symbol data base for the Structured Design System (SDS) which is used for entering circuits at graphics terminals and forms the common route into other packages in the system, ii) the model library for the logic design simulator HILO and iii) the cell outline library for the automatic cell layout system CAL-MP. The SDS data base contains circuit schematics of all cells as well as the basic symbols, while the CAL-MP library contains technology information such as signal and supply track widths and spacings, etc. Two designs have been completed and are currently awaiting mask making and fabrication. The first user course is scheduled to be held in January 1986.

NCA Design Verification Software

After initial teething troubles, this major software package has proved to be an essential tool in the CAD system. 15 designs from five universities (Edinburgh, Leeds, Manchester, Newcastle and Strathclyde) have been processed by RAL staff to remove geometrical and electrical design rule violations prior to fabrication. More than 30 designs have been processed by the SERC Brokerage using the mask layout software section of the NCA system.

Other Software

New versions of several software packages have been evaluated during the year and installed where appropriate. SDS Version 5, which allows the designer to edit symbols and schematics in a number of windows displayed simultaneously on the screen, was evaluated during the autumn and released to users in December. Tests were carried out on the SIMON simulator available through ECAD Ltd as an alternative to SPICE for circuit simulation. These showed that SIMON is very fast for large digital circuits but that gains are less substantial for analogue circuits.

Interfaces to Other Systems

Most designs have been committed to silicon using the Electron Beam Lithography Facility (EBLF) at RAL and the SERC Microfabrication Facilities at Edinburgh and Southampton. Many of the designs now require access to other mask making and fabrication houses, and a decision has been taken that routine processing should use commercial facilities. RAL staff are providing the interfaces to other systems required for successful running of the SERC Brokerage Service. HILO simulation data and UK5000 test generator data can now be sent to a Hewlett-Packard functional tester. A graphics driver is being written to enable plots to be produced on a high quality Versatec plotter for all designs using the Brokerage Service. A program has been written to enable designs entered through SDS and simulated by HILO to be sent for fabrication using the gate array service run by Microcircuit Engineering Ltd. Symbol and model libraries have been produced for SDS and HILO. Software has also been written to interface the CAD system to the Laboratory's Artworker PCB systems (Fig 2.4) allowing a designer to enter a logic schematic using SDS, convert the gate description into standard IC packages and send it to the Artworker for layout.

Computers

Most designers access two PRIME computers at RAL (a 9950, soon to be upgraded to a 9955, and a 750) from terminals in their departments connected to JANET, the Joint Academic Network. They submit batch jobs to the central IBM-compatible computers at RAL for

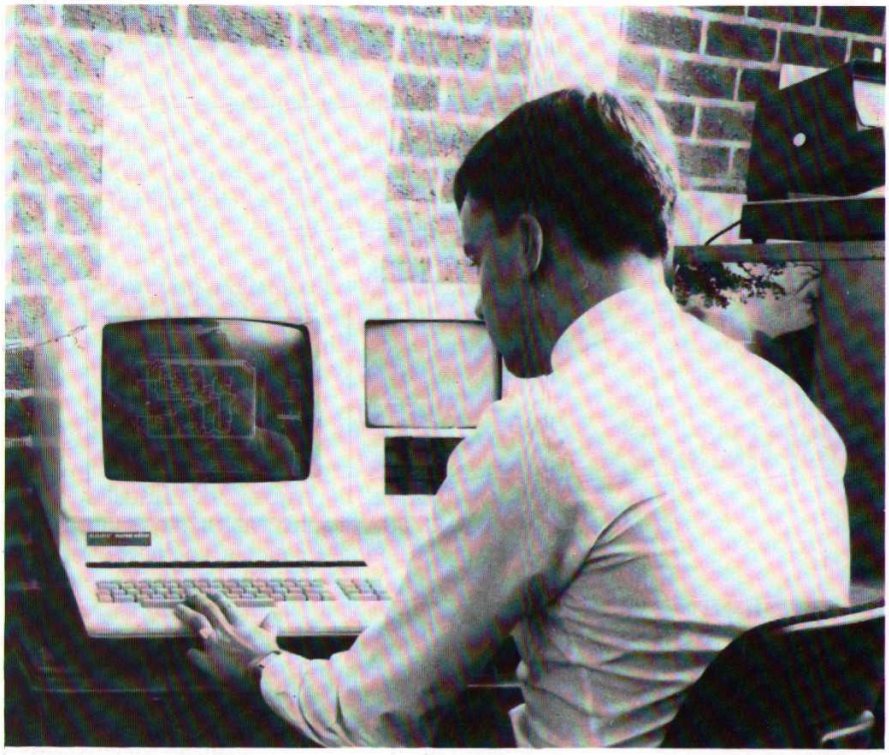


Fig 2.4 Wayne-Kerr Artworker used for testing printed circuit boards. (85RC5366)

checking and simulation of design. RAL staff have managed the installation of design software on three PRIME computers at Hatfield and Middlesex Polytechnics and at UMIST. They are working closely with university staff to distribute software to local systems in university departments in a coordinated manner. A MicroVAX II is being purchased to enable RAL staff and university users to access new versions of software which are not available on PRIME computers.

Support

Training courses are held regularly to teach effective use of the CAD tools. The SERC Electronics CAD User Group held a meeting in Manchester in April and RAL organised a meeting for electronic designers in SERC establishments in October. Both meetings were attended by more than 80 people.

INMOS Workstation

RAL took part with Edinburgh and Newcastle Universities, ICL, MCE, Racal-Redac, Racal Microelectronics Systems, Sinclair and INMOS in a project funded by the Alvey Directorate to evaluate the INMOS workstation within a general-purpose environment. The workstation was developed by INMOS to satisfy its internal needs. RAL concentrated on a comparison of the simulator with other tools and preparation of design rules and device models for the Plessey 5μm process. It is intended that the workstation will be used at RAL for the design of specific cells to add to cell libraries.

Integrated Circuit Design

Integrated circuit design software is being used to design applications specific integrated circuits for three SERC-funded activities. The first is concerned with the design of CMOS analogue circuits and the extent to which the various detectors used in scientific experimentation can benefit from the versatility of an integrated circuit approach. Three circuits are being considered covering a range of noise levels and degrees of integration. In the second case, the application of bipolar circuits to the problem of time interval measurement is being studied and, again, the aim is to explore the advantages that custom integrated circuit design brings. The third is concerned with the development of large-scale integrated circuits to support computer vision studies. This will provide a set of circuits implementing a number of the 'local neighbourhood' operators required for low-level image processing. These programmes have used the various SERC microelectronics facilities as well as industrial sources for mask making and for silicon processing.

Microelectronics Brokerage

To assist academic microelectronics research, SERC has set up a Brokerage service to provide interfaces with Industry. One such responsibility is the making of arrangements for CAD, mask making and device fabrication in both silicon and compound semiconductors through the use of proven industrial facilities. SERC has also established five Design and

PLATE I
Millimetre Wave Telescope under construction on Mauna Kea, Hawaii at 4,300 m altitude. (85 RC 4789)

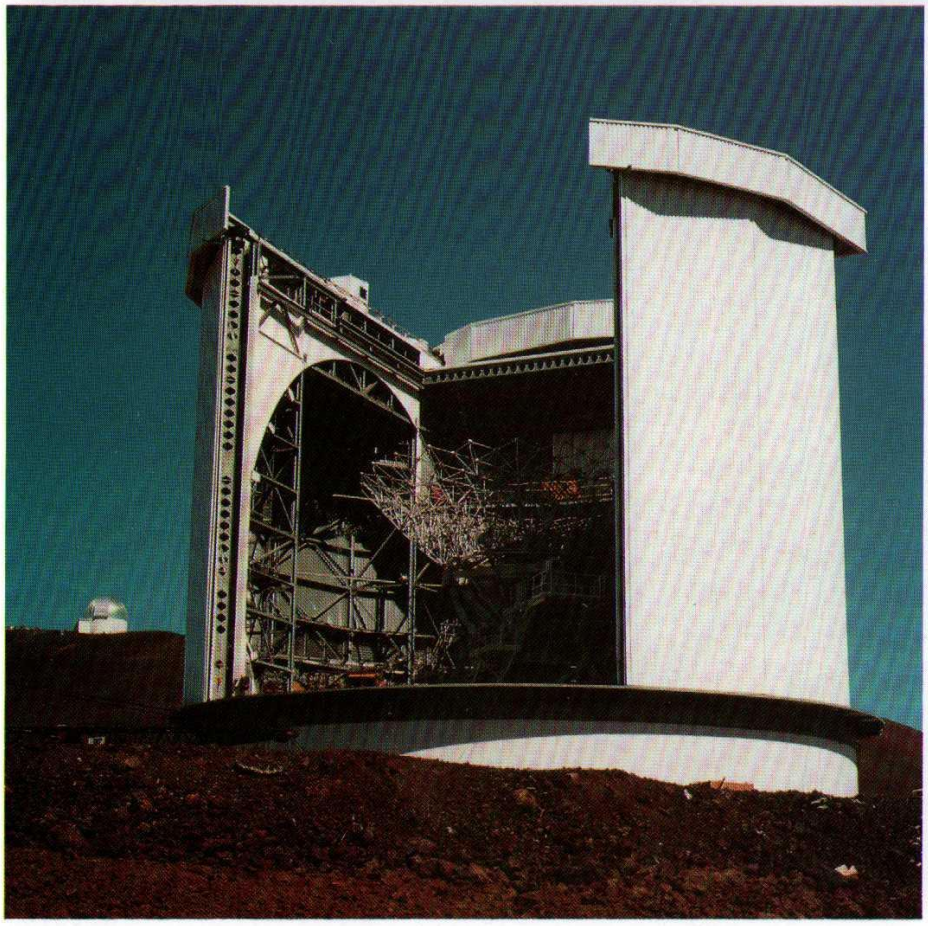
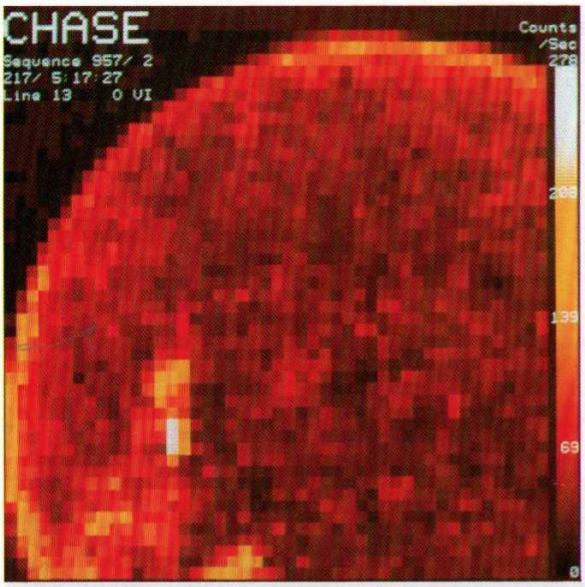


PLATE II
The Telescope structure being installed in its rotatable housing. (85 RC 4916)



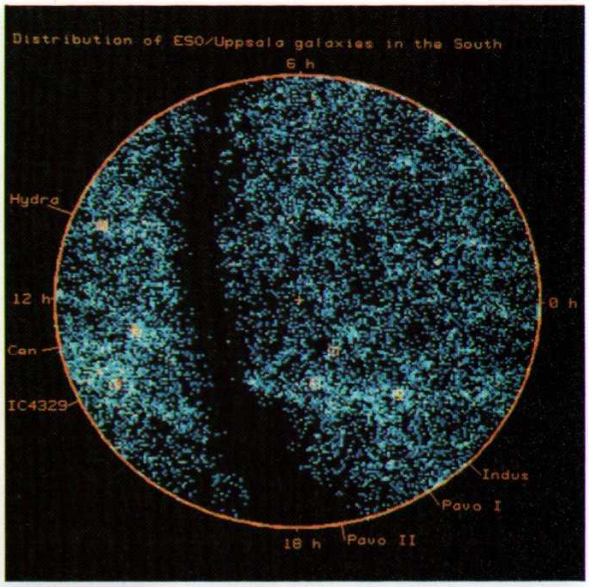


PLATE III
Raster map of part of the Sun's disc and corona. An active region on the disc is easily discernable. The limb brightening seen round the edge of the disc is absent at the coronal hole near the south solar pole.

PLATE IV
STARLINK reveals the clustering of galaxies. (86 RC 1095)

PLATE V
The Hubble Space Telescope, due for launch in 1986. (By Kerby Smith (c) 1981 National Geographic Society)

PLATE VI
The nearby spiral galaxy in Andromeda as seen through the infrared eyes of IRAS at two wavelengths. The intensity of radiation is colour-coded from blue (weak) to white (strong). (86 RC 1034)

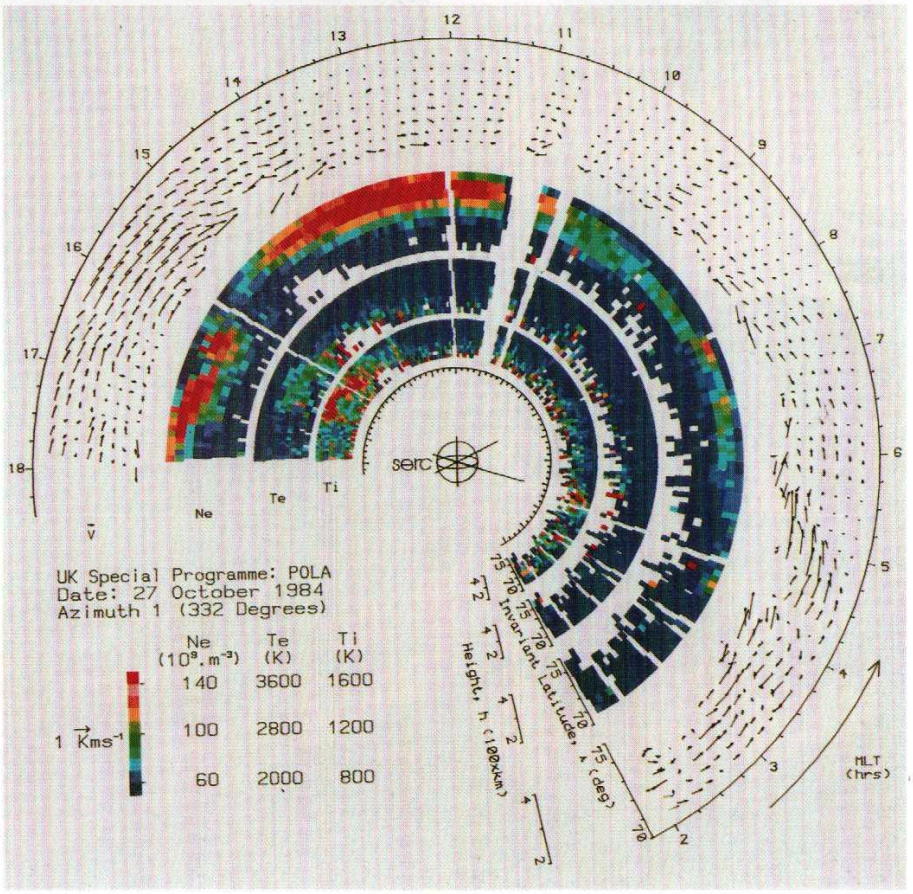


PLATE VII
EISCAT data showing the response of the high-latitude ionosphere to a southward turning of the interplanetary magnetic field at 1400 hrs Magnetic Local Time. (85 FC 5720)

PLATE VIII
Photograph of Halley's Comet taken on 12 January 1986 by A L Lintern and P D Wroath (retd.) of RAL.
An 8-inch Schmidt Cassegrain telescope, focal length 1000 mm was used at f5 with a telecompressor and the exposure time was 10 minutes.
In this picture the Comet exhibits a curved tail, a feature noticed in November.
The orange-brown background is skyshine from the sodium street lighting of Swindon.

PLATE IX
SUN 2, Whitechapel MG-1 and PERQ 2 single user systems showing the range of graphics these systems can provide. (85 FC 5609)

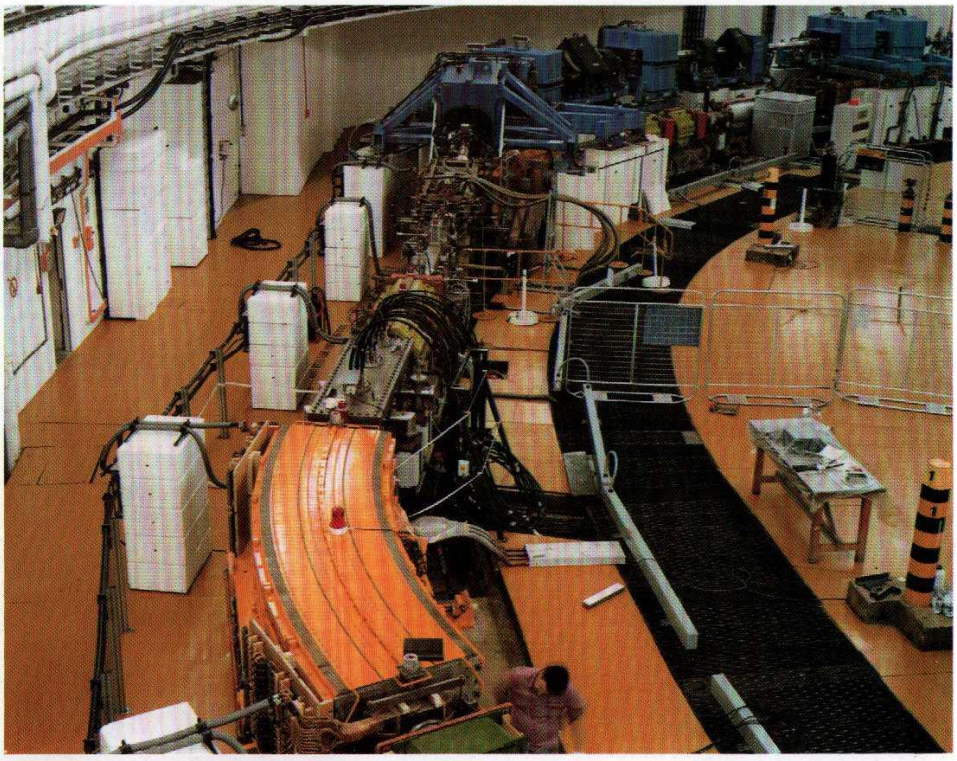


PLATE X
Part of the ISIS synchrotron showing one of the ten dipole magnets in the foreground, kicker magnets which deflect accelerated protons into the extraction beamline channel and the start of the extracted beam line, at rear centre.
(85 RC 2819)

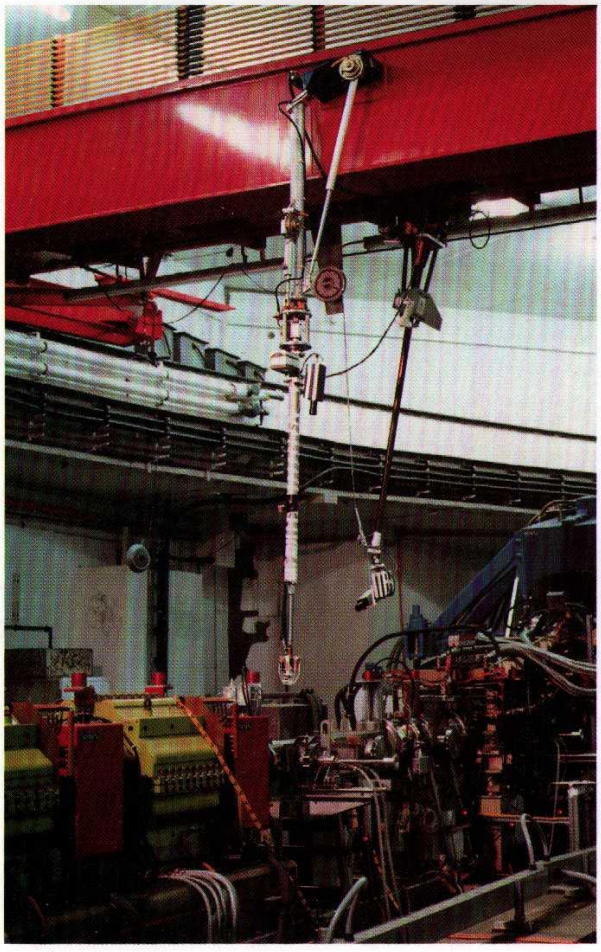


PLATE XI
ISIS remotely controlled arms carrying radiation probe and closed circuit television camera, attached to radio controlled crane.
(85RC1590)

ISIS

Inauguration and Naming by The Prime Minister 1 October 1985

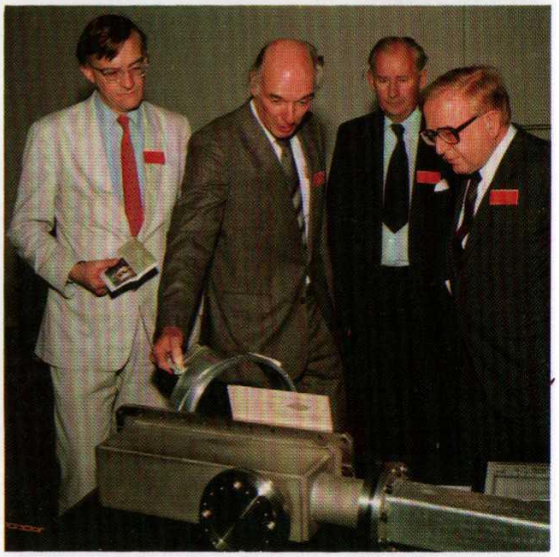


PLATE XII
ISIS Naming and Inauguration Ceremony.

Centre (L–R): Dr G Manning (Director RAL). The Prime Minister, Prof E W J Mitchell (Chairman SERC), Sir John Kingman (former Chairman SERC).

Top left: Prof R Chabbal (France), Mr Alan Carne (RAL), Prof A J Leadbetter (RAL), The Prime Minister, Sr J M Rojo (Spain).

Top right: Dr Manning, Sig L Granelli (Italy). The Prime Minister, Prof Chabbal.

Bottom left: Mr D A Gray (RAL), Mr J L R Huydecoper (Netherlands), Mr Geoffrey Pattie MP (DTI), Mr T Abrahams (DTI), Hon Peter Brooke MP (DES), Dr P A J Tindemans (Netherlands).

Bottom right: Mr Robert Jackson MP, Mr H Wroe (RAL), Sir Trevor Skeet MP, Prof A Vaciage (Italy).

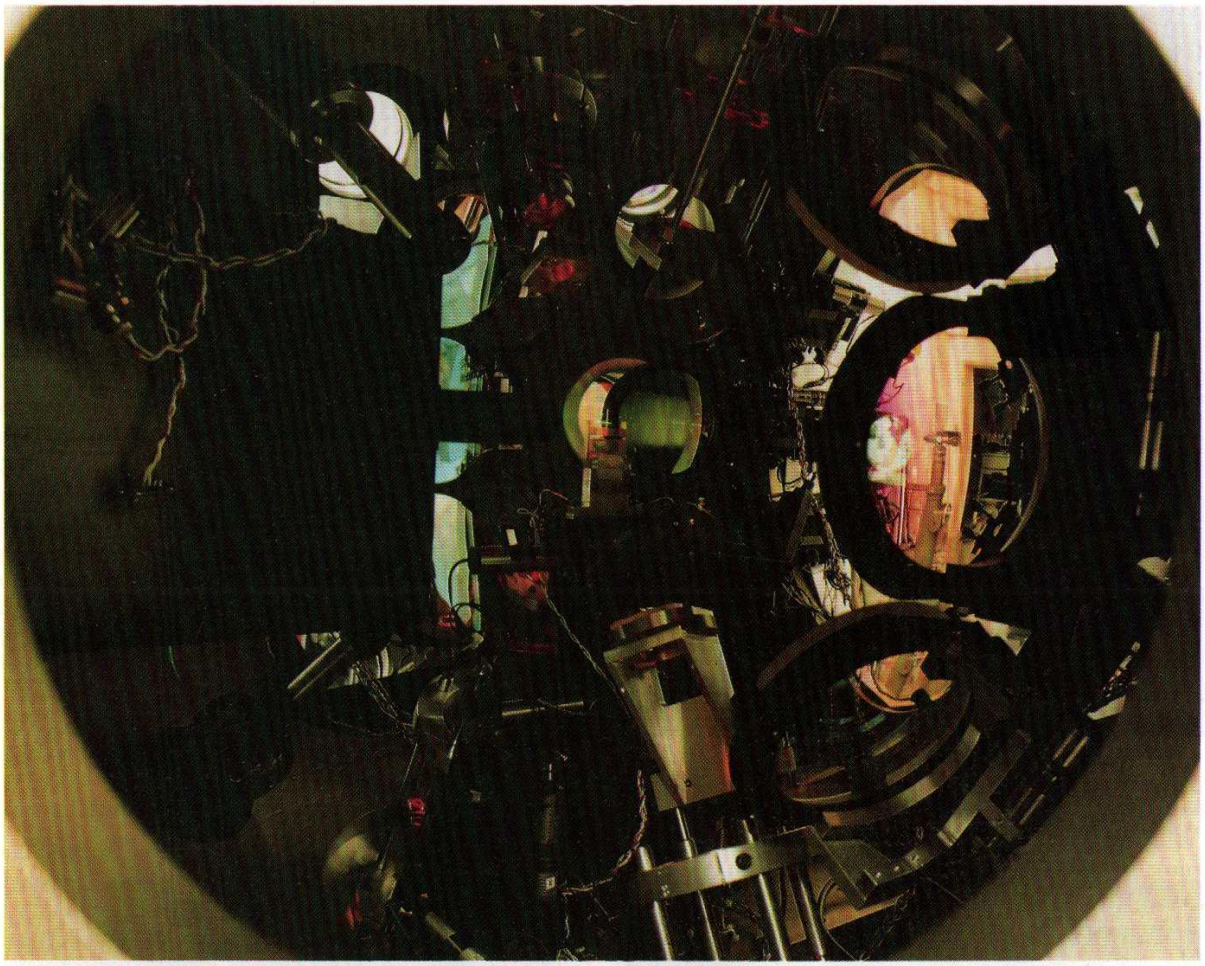


PLATE XIII
The new VULCAN laser target chamber, showing optics to produce line-focus illuminations for x-ray laser research. (85 RC 5376)

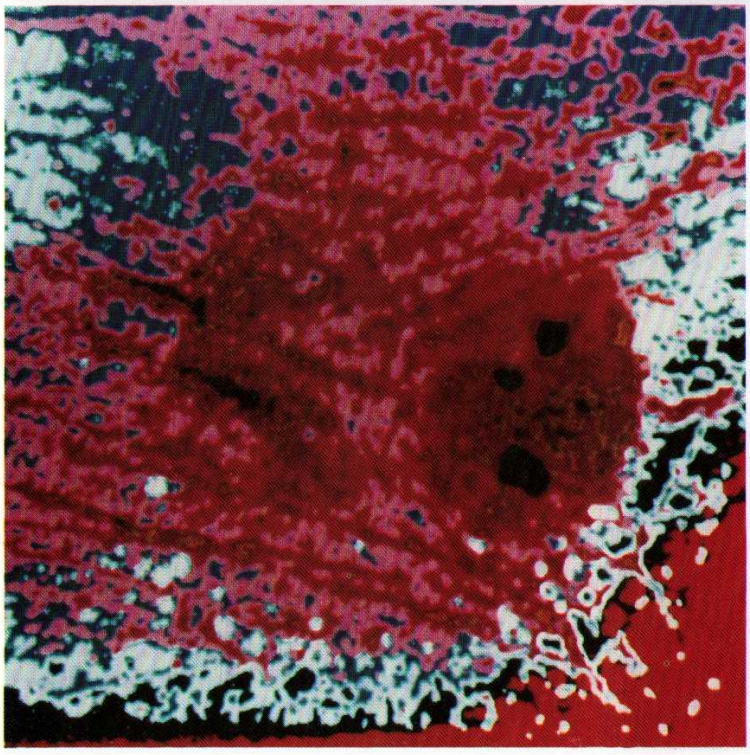


PLATE XIV
False colour flash x-ray image of unprepared human fibroblasts. The photoresist used to record the image has been enlarged by a transmission electron microscope. (IBM)

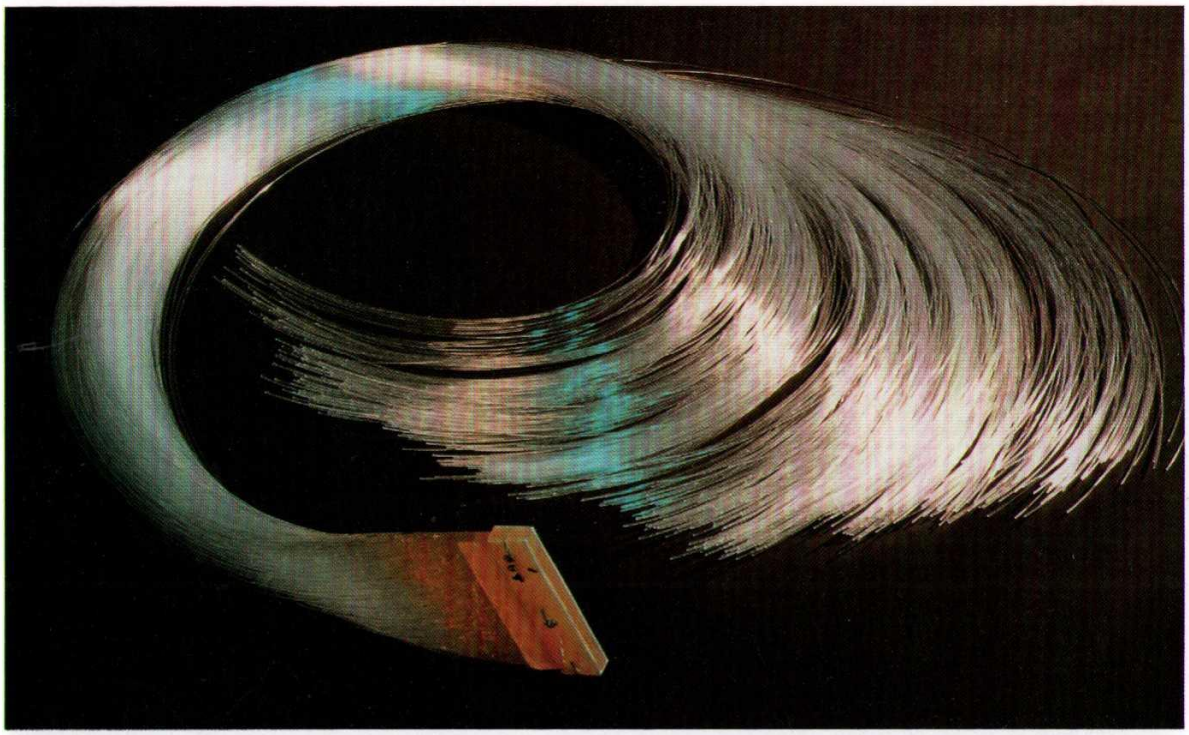


PLATE XV
One of the twenty four optical fibre light-guides for the HELIOS experiment (Expt 260) at CERN. Each guide comprises 700 x 1 mm fibres. The advantage of using fibres is their flexibility and the ease with which they can be bundled into a circular cross-section at the photomultiplier. (85 FC 2967)

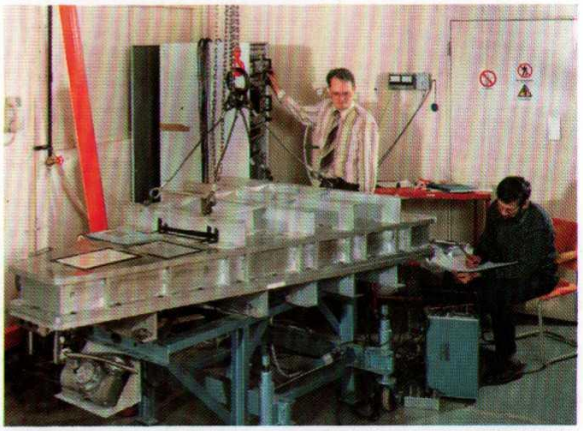


PLATE XVI
Checking the high voltage integrity of six of the proportional wire tube layers of the ALEPH End Cap Calorimeter using the vacuum tight test vessel. All 1080 layers must pass this test before being assembled into the calorimeter. (86 FC 1014)

PLATE XVII
Assembling the Proportional Wire Tube layers for the ALEPH End Cap Calorimeter. Each layer of 220 fine gold wires is accurately tensioned and laid into 22 lengths of aluminium extrusion. (85 FC 5430)

Test Centres at Newcastle University, Edinburgh University, UMIST, University College London and Southampton University to advise the academic community on integrated circuit design and testing. Three of these are linked to UK industrial processing (Newcastle to Plessey, UMIST to Ferranti and UCL to GEC) and the Brokerage team at RAL provides this link.

Lithography

Lithography is the technology which has underpinned the enormous progress made in microelectronics in the past 15 years. Most industrial microelectronic processes use optical lithography at wavelengths between 350 and 450 nm. Advances in this technology, aimed at reducing feature size to below 1 μm, are taking place by reducing the wavelength to 200 nm and by the use of electron beam and X-ray illumination sources. The Board has contributed to each of these areas, in collaboration with Industry, through Department of Trade and Industry (DTI) and Alvey projects. The programme in X-ray lithography using the synchrotron at Daresbury Laboratory was successfully completed. Work with electron beams and EUV excimer lasers has produced exciting advances during the course of the year.

Electron Beam Lithography (EBL)

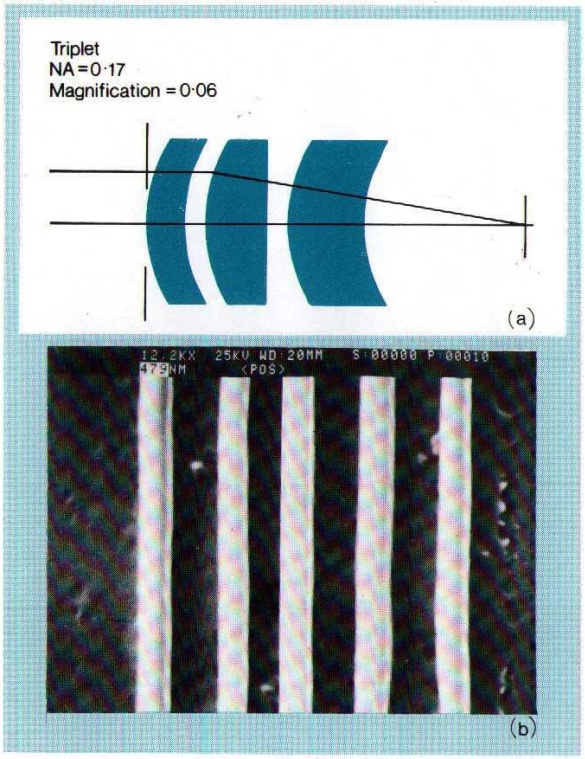
Building on experience gained in constructing and operating the electron beam lithography machine RAL1 at the RAL Electron Beam Lithography Facility, an Alvey project has been initiated in collaboration with Cambridge Instruments and Cambridge University to complete the next generation of microfabricator by 1989. This machine will be the basis of British competition in high-precision, high-throughput electron beam machines and will increase writing speed by a further factor 20. If successful, the time taken to write the mask plate will be comparable with the time taken to expose the silicon wafer through a mask, making direct writing on to the silicon wafer a practical proposition. The potential benefits of utilising the good resolution and registration ability of the electron beam microfabricator in direct writing on to silicon will revolutionise silicon fabrication methods and substantially reduce the time between chip design and completion.

The development work on microfabricators is complemented by an Alvey programme in collaboration with British Telecom, Compugraphics International, Ferranti Semiconductors and GEC Hirst Research Laboratory for the development of mask-making technology to obtain a production process for feature sizes less than 1 μm. Early results from this programme have reduced the variation in linewidth to below 0.1 μm, which is the resolution required for 1 μm lithography. The Facility has benefited from work within the collaboration in reducing defects on mask plates and a quantitative model for linewidth control is being evaluated. Automated mask plate inspection will be carried out by a Cambridge Instruments 'Chipcheck' machine in the Facility which will compare completed mask plates with the CAD original and log discrepancies. Another Alvey project, in collaboration with Manchester University, is developing direct write techniques for use with gate arrays, and direct write on silicon is being investigated in collaboration with Southampton University.

Use of Excimer Lasers for Microelectronics

Excimer lasers provide an intense coherent light source at wavelengths between 150 and 450 nm. A project to exploit excimer lasers to provide British industry with state-of-the-art sub-micron printing equipment has been funded jointly by SERC and DTI. This programme uses the coherent nature of laser radiation to exploit new ideas in image formation using both holography and phase conjugation. This approach has the potential of producing sub-micron lithography without the difficulties of designing conventional high performance systems to operate in deep UV. A complementary programme to design conventional optical systems utilising the intense short pulses from the excimer laser (10–15 ns) will combine the benefits of improved resolution obtained by using shorter wavelengths (249 nm and 193 nm) and the decrease in exposure time with the corresponding increase in throughput gained by using the laser. Exciting progress has been made in both areas of work. Sub-micron

Fig 2.5 Triplet lens (upper) used to projection-print the 0.5 μm lines shown (lower). (85FC6524/85FB4629)



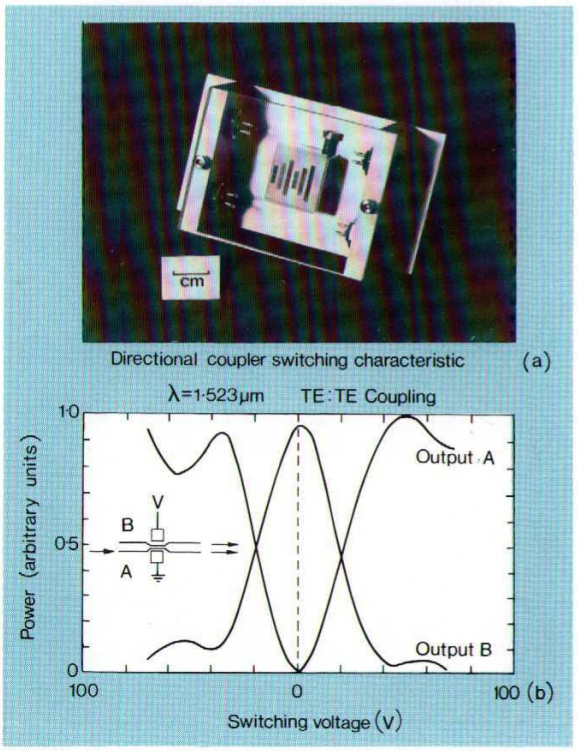
lithography has been demonstrated using both holography and phase conjugation techniques. The potential of using a hologram in place of a lithographic mask has been realised, and two schemes are being evaluated in collaboration with Industry. Several methods employing phase conjugation are being developed. These techniques use a sophisticated phase-conjugate mirror to reverse both the phase and direction of a wavefront. In this way, any aberrations produced in an optical system are cancelled and cheaper optics can be employed. The programme is now concentrating on translating laboratory demonstrations into practical tools for exploitation by Industry.

Using conventional lenses, sub-micron lithography has been demonstrated with a projection reduction system. Using the high contrast characteristics of resists, feature sizes less than the Rayleigh diffraction limit have been obtained. Fig 2.5 shows an inexpensive triplet lens constructed of fused silica used to produce lines smaller than 0.5 μm. The design of four full-scale optical systems is well advanced and will be available for evaluation by Industry during the next year.

Applications of Lithography to Integrated Optics

Microfabrication of special devices has always formed part of the lithography programme. This year, a collaboration with Oxford University has started to design, fabricate and test integrated optic devices for applications at a wavelength of 1.5 μm. Initially, the programme has concentrated on establishing the techniques for fabricating and testing devices. An example of such a device is shown in Fig 2.6. Two optical waveguides are formed in the surface of an optically-active material ($LiNbO_3$). Coherent light from a laser entering waveguide A is coupled to waveguide B when the two guides are separated by a few microns. The degree of coupling can be controlled by a voltage applied to electrodes placed above the coupling region, and light can be switched between waveguides. A significant number of devices have been successfully tested to determine the dimensional tolerances required to optimise the coupling process, and systems including many devices are being designed. The applications of integrated optics are numerous and include telecommunications, sensors, signal processing and optical computing.

Fig 2.6 Array of 6 integrated optic directional coupler switches bonded and packaged for testing, and a typical test result. (Oxford University)



Radio Research

The planning and realisation of future communication systems requires an understanding of the merits of wired and radio-based systems. Although it would appear that conventional telephone systems might be a prime candidate for a wired system, considerable interest is currently being generated by the possibilities of wire-less PABX systems. Clearly, mobile application, satellite communications, temporary links and communications to remote areas are made viable through radio-based systems. An essential element in the planning of any radio-based communication is a detailed understanding of the propagation media. The research activity of the Radio Communications Research Unit has continued to concentrate its efforts on the study of propagation problems relevant to future systems by conducting a broad-based programme on behalf of the Departmental Users Committee.

Terrestrial Path Studies

The collection of attenuation data at millimetre, infra-red and optical wavelengths has continued on the 500 m range at Chilbolton. The main emphasis during the year has been concerned with the development of a near-instantaneous snow and hail gauge and the installation of humidity and temperature measurement devices capable of recording vertical profiles near the ground. Analysis of individual events has produced interesting results on both snow attenuation and propagation through intense flames. The latter exercise, performed in conjunction with Britoil, indicated scintillation with spectral characteristics different from those in clear air. Fig 2.7 indicates these differences where the scintillation resulting from the turbulence in the flame produced a −11/3 power law, compared with the −8/3 law expected for clear air

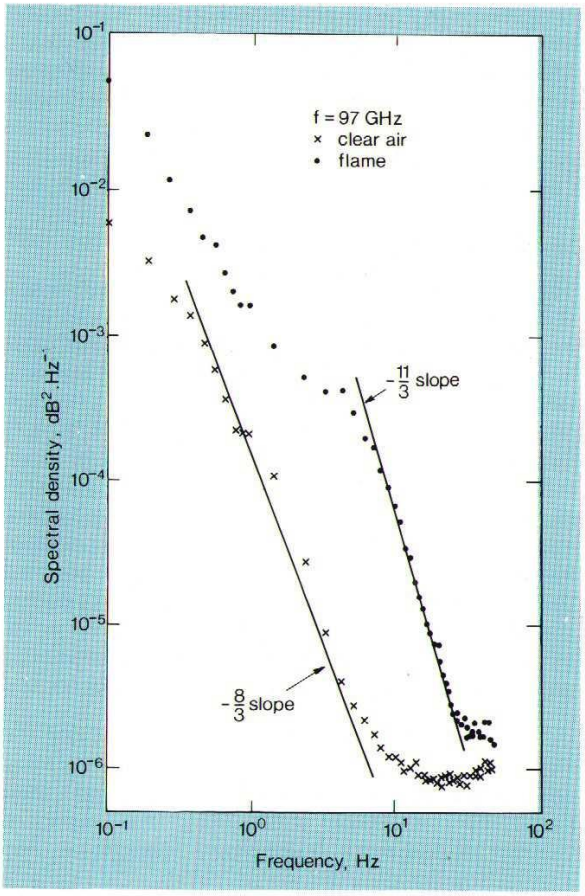


Fig 2.7 Radio propagation measurements of spectral densities of scintillations due to turbulence in clear air and flames.

scintillations. Investigations of multipath at microwave frequencies are being conducted on a 29 km link at 18 GHz. The engineering trial of a 250 Mbps pseudo-random sequence transmission system combined with a correlator receiver has been conducted successfully. This system will yield data on the instantaneous variation in amplitude and phase of the transmissions over bandwidths up to 1 GHz. An aircraft-mounted refractometer has also been developed which will be used to measure the refractivity structure of layers in the troposphere. This instrument will be used to assist both multipath and clear air interference investigations.

Transhorizon Propagation

Anomalous propagation in clear air by ducting and through rain scatter is being studied, with an objective of improving interference modelling between remote transmissions using similar frequency allocations. The results of a preliminary rain scatter experiment at 18 GHz, in which the rain radar system was used to characterise the precipitation causing the scatter, have now been analysed. Agreement between the direct measurements and those derived from the radar were encouraging. A collaborative experiment between CNET (France), Portsmouth Polytechnic, the Independent Broadcasting Authority and RAL is currently being installed to investigate anomalous propagation across the English Channel. Preparation of the equipment and installation on the experimental site is proceeding, measurements being expected in 1986.

Earth-Space Paths

The main experimental activity has been concerned with the collection and analysis of data on a low elevation path from measurements on the 11 GHz beacon on the Indian Ocean Intelsat 5 satellite. The University of Essex and Portsmouth Polytechnic have assisted in this experiment. The ESA Olympus satellite, scheduled for launch in the latter half of 1987, will support a comprehensive beacon payload at 12, 20 and 30 GHz. RAL has been active in planning these future experiments through the coordination of the European Space Research Technical Centre (ESTEC). Investigations of slant path effects in the millimetre bands are currently being sponsored by the Royal Signals and Radar Establishment (RSRE). A dual-frequency radiometer (78 and 94 GHz), which is undergoing the final stages of development, will be used to obtain propagation data on slant paths at a variety of inclination angles through passive sounding and Sun-tracking modes.

Propagation Studies at VHF and UHF

Comparisons of the relative merits of computer-based signal strength prediction techniques have been made during the year. These are of special interest for mobile radio systems. Signal strength measurements supplied by British Telecom for the Ipswich area are shown as a contour plot in Fig 2.8 a) and may be compared with predictions by a computer-based method shown in b). It is planned to apply this contour approach to investigate interference effects, in particular for cellular mobile radio systems.

Communication Studies

Communication studies have been concerned with future experimental satellite communication systems. A more detailed study of the mobile communications payload, first conceived as part of the proposed Communications Engineering Research Satellite (CERS), is currently being coordinated through RAL. The main objective of this one-year programme is the production of breadboard sub-systems to demonstrate the proof of concept of the payload elements. The Universities of Bradford, Manchester, Loughborough, Surrey, London (King's College and Queen Mary College) and Portsmouth Polytechnic are undertaking the detailed aspect of this study. A related design study has been undertaken for the Technology Satellite, T-SAT. The objectives of this project are to promote a design initiative which will stimulate the development of space technology and training within the UK university community and to conduct a design study on

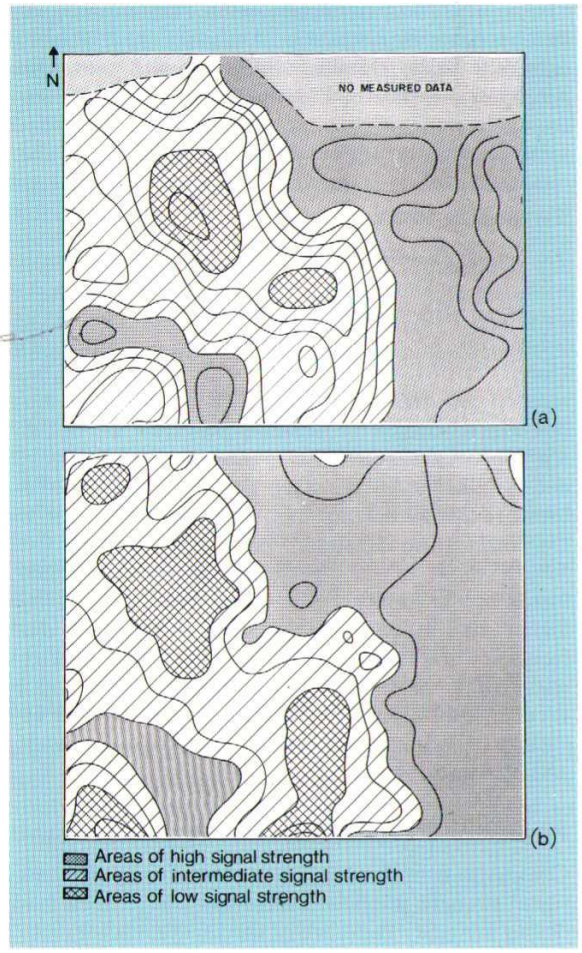


Fig 2.8 Radio signal strength contours in the Ipswich area at 900 MHz, a) measured, b) predicted.

the spacecraft itself, the primary payload being based on CERS. As with the propagation studies, planning for the future communication experiments associated with the 20/30 GHz payload on Olympus has commenced. Although in its early stages, three projects are under consideration concerned with i) very small low-cost Earth station technology, ii) novel and adaptive access techniques to overcome propagation impairments caused by excess rain attenuation and iii) the characterisation of the propagation medium for very high bit rate transmissions, which could operate at speeds of several hundred Mbps.

Satellite Communication Experiments

The interconnection of Local Area Networks through broadcast satellite channels was investigated in the UNIVERSE project. This work has continued in the UK with a collaboration between RAL, Loughborough University of Technology and Manchester University. RAL has also continued this work in Europe with the Technical University of Graz, Austria, and CNUCE in Pisa, Italy. A variable rate modem capable of operating at 1, 2, 4 or 8 Mbps is being developed at Loughborough University of Technology. Manchester University is designing a variable rate coder/decoder. These developments will allow access to satellite channels with between 10^{-4} and 10^{-11} bit error rate. A controller developed by GEC Marconi will be used to test this equipment in 1986, probably on the ECS Communications Satellite.

Ionosondes

The operation of the three observatory sites at Slough, South Uist and the Falkland Islands is the joint responsibility of the ASR and Engineering boards. The transmission of digital data by landline from the new ionosonde at Slough to RAL and other users has proved reliable and satisfactory. Magnetic tapes and film records are processed and archived at the RAL World Data Centre. The Slough and South Uist ionosondes have been used recently in support of a worldwide Atmospheric Gravity Wave Campaign. Plans to replace the ageing ionosondes at South Uist and the Falklands with container-housed digital sondes are well advanced.

Ionospheric Prediction for HF Communications

RAL has maintained its service of providing advice and assistance to the UK radio-user community concerning ionospheric propagation characteristics and their significance to specific radio links. An important element of the work is long-term ionospheric and propagation modelling and a number of existing computer-based procedures have been maintained and improved. Predictions have again been supplied in support of a range of university and RAL projects. Theoretical studies have included a review of available methods of estimating the reliability of broadcast reception. Attention is being devoted to the development of microcomputer-based predictions for small-user and mobile applications.

International Activities

The Laboratory has continued to support the activities of the International Telecommunication Union (ITU) through active participation in study groups of the International Radio Consultative Committee (CCIR). At CCIR request, computer programs concerned with ionospheric propagation based on internationally established technical procedures have been developed, documented and provided for implementation in Geneva. A CCIR Working Party chaired by RAL assembled a data base of field-strength measurements for use in a new ITU plan which will re-organise the world's high frequency broadcasting.

Propagation Studies at Universities and Research Organisations

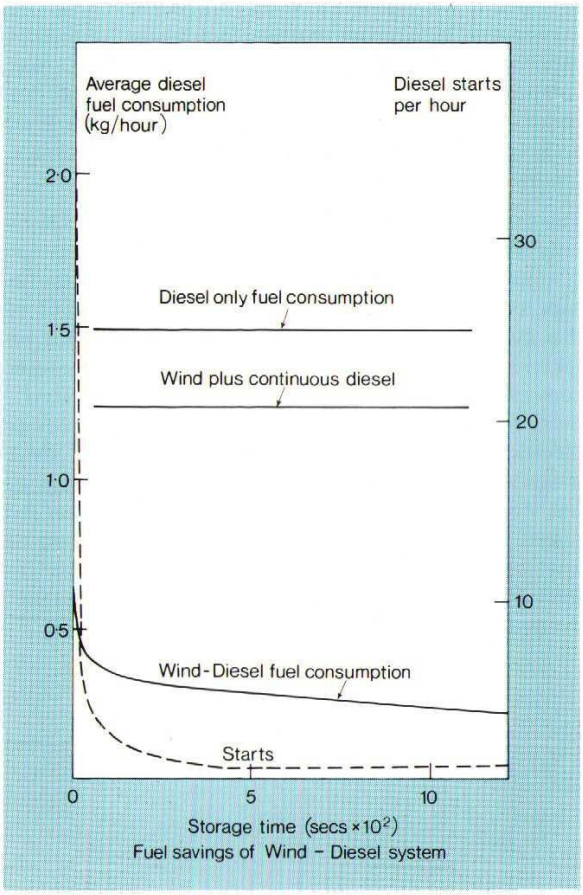
As part of the programme sponsored by the Departmental Users Committee, the Laboratory assumes responsibility for extramural research contracts placed mainly with university departments

although some are undertaken by industrial research organisations. Current topics include research on rain scattering, mobile, urban and mixed land/sea propagation, interference studies, high-latitude ionospheric modelling, short-term ionospheric forecasting and studies of high-latitude ionospheric scintillations.

Microwave Laboratory Measurements

The RAL untuned cavity, with its effective path length of 500m, has been used to measure the absorption of microwaves (23–40GHz) in moist air under controlled conditions of temperature and humidity. This frequency band is used for satellite remote sensing and an accurate knowledge of the atmospheric behaviour is essential. Moist air absorption measurements are currently being made (in collaboration with the Meteorological Office and Laboratoire de Meteorologie Dynamique, Paris) at frequencies between 80GHz and 180GHz, in support of the Advanced Microwave Sounder Unit (AMSU) to be flown on future meteorological satellites. In addition, smaller cavities are being used to study the dielectric properties of liquid water and ice at these frequencies.

Fig 2.9 Fuel saved when a diesel power system is supplemented by wind energy.



Sea-State Radar

The Ocean Surface Current Radar (OSCR) is now being used on a commercial basis. It was developed at RAL as part of the sea-state radar programme and, as its name implies, is used to map the current flow patterns in coastal areas using a beam scanning technique similar to that employed in conventional radars. In May, the Institute of Oceanographic Sciences, Bidstone, used OSCR for a survey of the North Wales coast during which the system was operated continuously for a complete lunar cycle. The various tidal components of the current flow were determined simultaneously at 144 different locations covering an area of 350km^2. Such data are invaluable for tidal modelling work and could not have been obtained using conventional oceanographic instruments. In July and August, the North-West Water Authority used the system to gather information on current flow patterns off the Cumberland coast in three areas under investigation for siting a sewage outfall. The OSCR data will indicate the most favourable site in the context of beach pollution. From a radio propagation point of view the Cumberland campaign was also particularly valuable. The OSCR system was operated using inland sites and demonstrated for the first time that, providing the radars are located on sufficiently high ground, back-scattered sea echoes can be obtained using line-of-sight rather than ground wave propagation.

Energy Research

The Laboratory coordinates university-based activities in energy-related research supported by SERC and provides central facilities, both hardware and software. It also undertakes research in collaboration with academic institutions and other organisations. Although its remit covers all aspects of energy, most activities are related to wind energy. Hardware facilities at RAL used by the academic community include a 6m vertical axis wind turbine (VAWT), a 16kW horizontal axis wind turbine (HAWT), a 7kW diesel generator, two 18m meteorological towers and data logging systems. Software and computing support is also provided and use is made of various wind and system models available on the RAL mainframe computer. In addition, use is made of comprehensive wind and load data and data conversion software.

Current Projects

There are collaborative projects with five institutions, Imperial College, University of Strathclyde, Cranfield Institute of Technology, University of Leicester and University of East Anglia, all related to wind energy. The 16kW HAWT, with the 7kW diesel set, has continued to be used for a project aimed at producing a

fully operational integrated wind/diesel system suitable for application in isolated communities. The programme involves both experimental and theoretical work in which the problems encountered when a diesel set is operated in conjunction with a wind turbine are being studied in depth. These problems arise principally as a consequence of the highly variable output of the wind turbine and the need to operate the diesel set in as efficient a manner as possible. An important part of the theoretical work is therefore to develop an optimum control strategy using a 'modelled' system which can then be applied to the real system for evaluation. A further factor when operating a diesel set with a wind turbine is the number of diesel start-stop cycles, which influence both wear and efficiency, and early results showed that these can only be reduced to an acceptable level by the inclusion of some form of short-term energy storage. Fig 2.9 shows fuel consumption as a function of the number of diesel starts per hour and the energy storage time. In an extension of the programme, the benefits of including storage, using a flywheel clutch-coupled to the diesel, are to be examined. This will, in total, form a six-year cooperative programme of research involving RAL, Imperial College, Hawker-Siddeley Power Plant Ltd, which provided the wind turbine and diesel set, and J Laing Construction Ltd, which is providing the flywheel system. The VAWT is being used by a group from Cranfield Institute of Technology which has installed an instrumented 3m blade section on the machine to study unsteady flow and dynamic stall.

A collaborative Strathclyde, North of Scotland Hydro-Electric Board and RAL project has been under way for over a year to investigate the long-term potential of wind energy at possible turbine sites on Shetland. Analysis of meteorological data obtained from two hill top sites has commenced and a computer model of the Shetland grid is being developed which will enable the effects of various levels of wind penetration on the existing system to be assessed.

Preparatory work at the RAL Wind Test Site commenced in the autumn in readiness for the installation of a novel new design of HAWT conceived and built by Imperial College. In addition to studies of the performance and control of the microcomputer-controlled wind turbine, it is planned to test a novel single-phase induction generator (developed under another SERC grant). A new project to study 3-dimensional aerodynamic effects for horizontal-axis wind turbines is under discussion and would make use of the Imperial College machine.

Applied Superconductivity

Superconducting Materials

The materials test facility has been busy again this year making nearly 200 resistive transition tests and many measurements on high-current joints being developed for the DELPHI solenoid. New apparatus for measuring the change in critical current produced by mechanical strain in superconducting wires has been commissioned and modifications to improve the performance of the apparatus for resistive transition measurements at 10pV/m have been completed.

The resistive transition tests were made in support of work at Cambridge University, for DELPHI conductor development (see Section 3), and for Industry. Almost 50 tests, including reaction heat treatments, were performed for Cambridge. Among other data, accurate measurements were required at an electric field of 1μV/m and these were made possible by the sensitivity of the RAL apparatus. Test facilities in Industry are limited in field and current to less than 7T and 1kA, respectively, so the facility at RAL continues to be the only one in the UK where tests at higher levels can be carried out. In a recent contract to produce 1.5 tons of superconductor for CERN quadrupoles, RAL was commissioned to perform the tests required for conductor heat treatment optimization and for the final acceptance tests. In all, over 100 tests were performed for Industry this year.

The critical field of niobium-titanium, even at 1.8K, is only 11T. Above this field, which is of interest for commercial NMR magnets, niobium-tin superconductor must be used. The critical current of this material varies markedly with strain and must be taken into account in winding design. Until the recently commissioned apparatus became available at RAL, there had been no measurements of the effect at lower electric field levels. These are essential for NMR magnets and an unexpected increase in strain sensitivity has been revealed. A sample thus mounted can be tested in the bore of a solenoid with the same ease as any other resistive transition test so that data on individual conductors can be made available to magnet designers.