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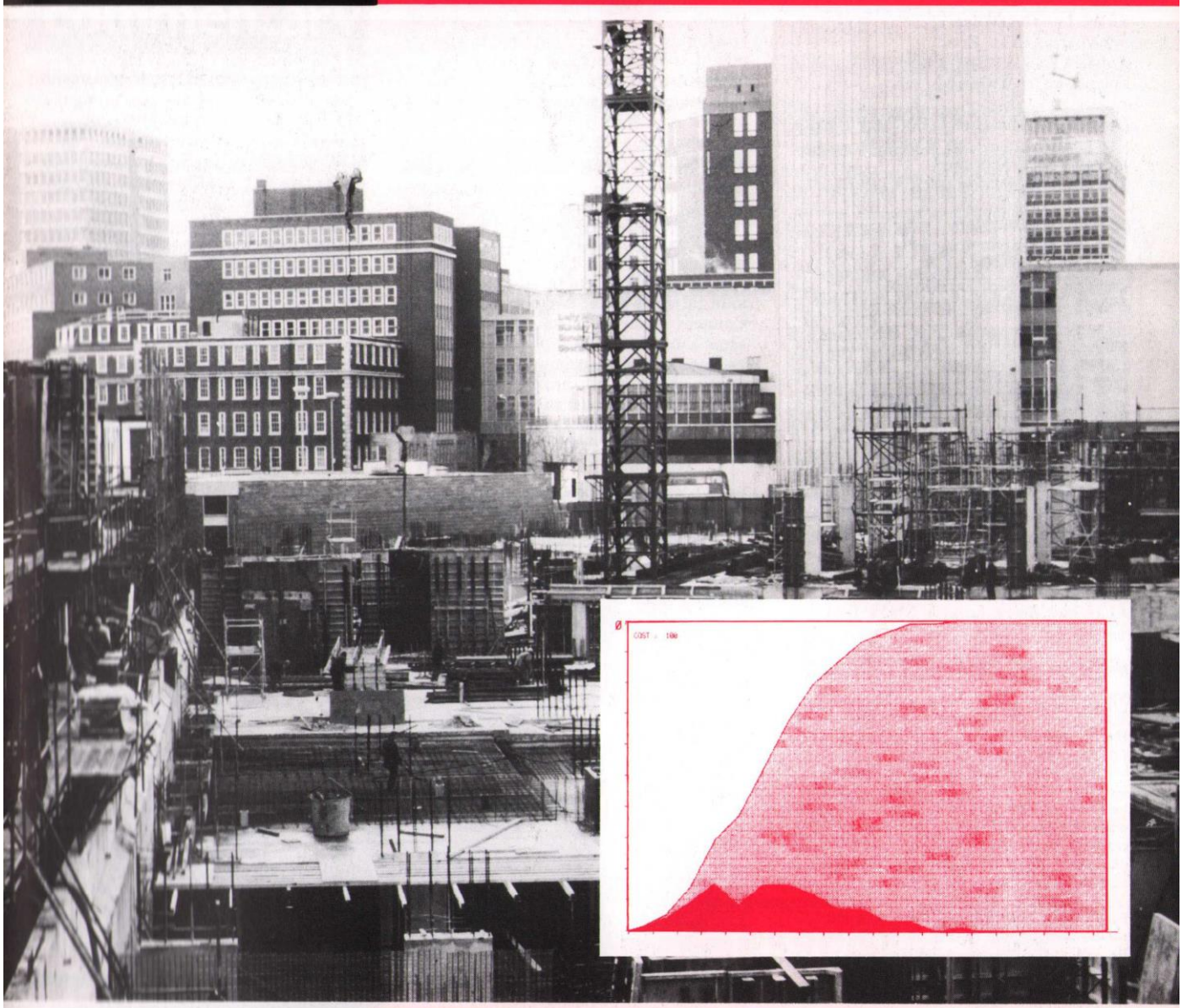

In this issue

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The Science and Engineering Research Council is one of five councils funded through the Department of Education and Science. Its primary purpose is to sustain standards of education and research in the universities and polytechnics through the provision of grants and studentships and by the facilities which its own establishments provide for academic research. The *SERC Bulletin* summarises topics concerned with the policy, programmes and reports of SERC.

Enquiries and comments are welcome and should be addressed to the editor, Miss J Russell, at the Science and Engineering Research Council, Polaris House, North Star Avenue, Swindon SN2 1ET. Tel Swindon (0793) 26222.

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Front cover picture

Construction management.
Inset is the output from the Reading University construction project simulator, designed to enable management to plan for and control the complexity and uncertainty which characterise the construction process. See page 8.

New support laboratory for biologists

The Biology Support Laboratory (BSL) was officially opened at Daresbury Laboratory on 29 November 1983. This new laboratory has been jointly funded by the Medical Research Council (MRC) and the SERC, to enhance the facilities for research with synchrotron radiation at Daresbury. It will provide the biochemical and biological support required to assay materials before and after exposure to synchrotron radiation, and to prepare and purify short-lived materials and solutions on site. A staff of five will support biologists using the SRS and will undertake their own research based at the BSL.

At the opening ceremony, Professor John Kingman FRS (Chairman, SERC) welcomed Sir James Gowans CBE FRS (Secretary, MRC) and referred to the joint interests of the two Research Councils: many advances in biology now came about from the application of very advanced physical techniques and equipment. The Synchrotron Radiation Source (SRS) was just such a major technical development, offering great research potential. Sir James responded on behalf of the MRC, expressing his pleasure in launching this joint enterprise to exploit the SRS in the biological field. He looked forward to the exciting results and discoveries likely to come about in the future, and wished the Head of the BSL, Dr Joan Bordas, every success.

Under the agreement between MRC and SERC, which was formally signed by Professor Kingman and Sir James, the costs of constructing and equipping the BSL, amounting to £450,000, will be shared beween the two Councils. The MRC will also contribute to the salaries of the five BSL staff members, and pay a proportion of the experimental programme and SRS running costs. Research grants in the areas of biological and medical science involving use of the SRS can now be funded by the MRC.

For further information on the new laboratory, and the facilities for biological research using synchrotron radiation, please contact Dr J Bordas, at Daresbury Laboratory; telephone Warrington (0925) 65000, ext 507.

Sir James Gowans (centre) visiting the new Biology Support Laboratory at Daresbury with Dr Joan Bordas (left), and Professor Leslie Green, Director of the Daresbury Laboratory (right).

Sir Morris Sugden CBE, FRS

Sir Morris Sugden CBE, FRS, who died on 3 January 1984 aged 64, was the Royal Society's Assessor to the Council. Sir Morris had been Master of Trinity Hall, Cambridge since 1976, Physical Secretary of the Royal Society since 1978, was President of the Chemical Society from 1978-79 and was formerly chief executive of Shell Research Limited.

Estimates 1984/85

Council has submitted its estimates to the Department of Education and Science for 1984/85 at a level of £278,827,000, as recommended by the Advisory Board for the Research Councils. This figure includes an additional £7 million as a contribution towards the increasing costs of international subscriptions which have resulted from higher levels of inflation abroad, a lower value of sterling and an increase in the UK share of those budgets where contributions are based on a relative calculation of the GNPs of member states.

Forward Look 1985/86 to 1989/90

In November Council gave preliminary consideration to its Forward Look submission and in February a fuller debate took place when Board Chairmen presented the Forward Look plans of their Boards. The final shape of the Foward Look submission to the ABRC was discussed in March.

International organisations

Council considered reports on its collaboration with various international organisations and, in December, approved contributions to the Institut Max von Laue-Paul Langevin (ILL); to CERN; to the European Space Agency and to the European Incoherent Scatter Scientific Association, and, in January, to the NATO Science Committee and the European Science Foundation.

Major new grants

NUCLEAR PHYSICS BOARD

In December Council approved an award of up to £1,149,000 for experimental research in nuclear structure physics at Oxford University (Professor K W Allen).

Congratulations

Elected Fellows of the Royal Society:

Professor T L Blundell (Birkbeck College, London), member of the Science Board and Chairman of the Biological Sciences Committee;
Professor B K Follett (Bristol), member of the Biological Sciences Committee;
Dr J R Krebs (Oxford), member of the Animal Sciences and Psychology Subcommittee;
Professor A G J MacFarlane FEng (Cambridge), member of Council and Chairman of the Central Computing Committee;
Professor P M Maitlis (Sheffield), former member of the Chemistry Committee;
Dr R N Perham (Cambridge), member of the Biological Sciences Committee;
Professor F H Read (Manchester), member of the Physics Committee and the Atomic and Molecular Physics Subcommittee;
Dr C H Llewellyn-Smith (Oxford), member of the Particle Physics Grants Subcommittee and the Nuclear Physics Theory Subcommittee.

Elected to the Fellowship of Engineering:

Professor G S G Beveridge (Strathclyde), member of the Engineering Board and Chairman of the Chemical Engineering Committee;
Professor B M Bird (Bristol), member of the Electrical Engineering Subcommittee;
Professor H H Rosenbrock FRS (UMIST), member of the Joint ESRC/SERC Committee;
Dr A W Rudge (Electrical Research Association Technology Ltd) member of the Information Engineering Committee and the Communications Subcommittee.

CREST/SERC courses in 'Informatics'

For many years the EEC and SERC have cooperated in the support of a programme of short advanced courses which encompass the 'Information Technology' subject area. Three or four such courses are supported in the UK each year, constituting only a part of the overall European programme.

The CREST/SERC courses usually last about a fortnight, are at postdoctoral-equivalent level, and are intended to be high quality. Lectures may be invited from Europe, USA, Japan, etc. The EEC provides up to 35% of the cost – subject to a reasonable attendance by European students – and SERC provide the rest. The courses offer high-level, state-of-the-art instruction on recent research in the selected topic. They are not intended as research workshops but are the next stage, perhaps, in the implementation of recent research. They are also useful for people from a related field who want to catch up in an area that is becoming vital to their work.

Scholarships can be provided for young academics and a few selected postgraduate students for fees and travel. Participants from industry are welcome but they will be charged a fee. Students from EEC countries can also be helped by a recently-introduced travel fund.

Recent topics and the institutions concerned are:
Strathclyde University: Local area networks
Cambridge University: Computer speech processing
Edinburgh University: The fabrication of VLSI circuits
Teeside Polytechnic: The quest for speed – subnanosecond digital electronics
Glasgow University: 3D Computer Graphics

If anyone is interested in mounting courses of this type from 1986 onwards they should get in touch with Mr T Hinde at SERC Central Office, Swindon (ext 2203) who will be able to provide more detail for potential applicants.

A new home for the ESRC/SERC Joint Committee

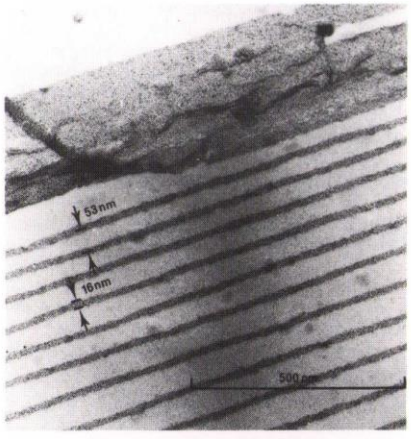
The Joint Economic and Social Research Council (ESRC)/SERC Committee was set up by the two Councils in 1968 following the Swann Report on *The flow into employment of scientists, engineers and technologists.* It was originally established to improve interdisciplinary postgraduate training. Since then its scope has expanded to include work that spanned the remits of the two Councils and in 1976 it was further expanded to include responsibility for research. The Committee has until now reported directly to the two Councils. Following a review carried out in 1983, it was agreed that from 1 April 1984 it would report to SERC's Engineering Board and ESRC's Industry and Employment Committee. This is expected to lead to a sharper definition of the Committee's priority areas, with emphasis on topics of interest to its new parent bodies, such as technology transfer and the management of innovation.

Miniaturisation at Glasgow

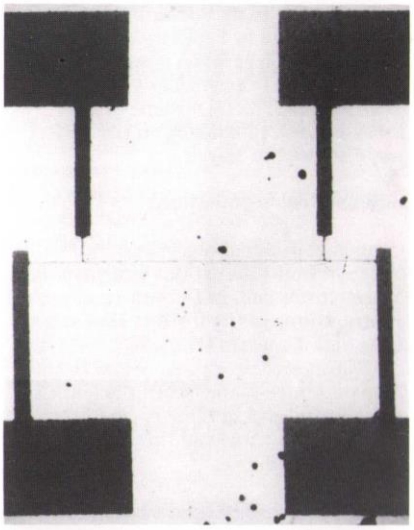
The microcomputer chip, carrying data on wires no larger than one fiftieth of the diameter of a human hair, has become a symbol of '80s technology. The components on which it relies, however, were invented half a century ago, yet they continue to function despite the dramatic miniaturisation required to pack tens of thousands of them into a square centimetre of silicon 'real estate'.

It is unlikely that the process of miniaturisation can be carried much further without accompanying changes in device behaviour. The physical processes on which field effect transistors, bipolar transistors and diodes rely set fundamental limits to the validity of accepted device theory. A transistor whose features are smaller than the mean free path of the current carriers or the separation between dopant atoms, or comparable with the wavelength of the electron, is unlikely to behave in a classical manner. These effects will not be significant, however, until device structure reaches 10-100nm in size which is well beyond the capabilities of even the most advanced photolithography. Research being carried out by the authors' group at Glasgow University's Department of Electronic and Electrical Engineering is developing lithographic techniques suitable for 10nm dimensions which it is hoped will allow size dependent effects to be probed.

The two viable candidates for very high resolution pattern definition are electron beam lithography and soft x-ray contact printing. Both have been examined in detail by the Glasgow group. The first of these, electron beam lithography, involves drawing the pattern in an electron-sensitive material with a focused electron probe. The sensitive layer, or resist, is usually a polymer and is coated on to the substrate to be patterned. Poly(methyl methacrylate) (PMMA) has the highest resolution of any polymeric



A typical resolution test pattern in 5nm thick platinum palladium alloy. Lines are 16nm wide and minimum centre-to-centre spacing is 53nm. Single layer PMMA resist, 50kV, 8nm electron beam.



A 40nm-wide gold-palladium 4-point probe test structure for low temperature electron localisation studies. The wire is approximately 25 microns long.

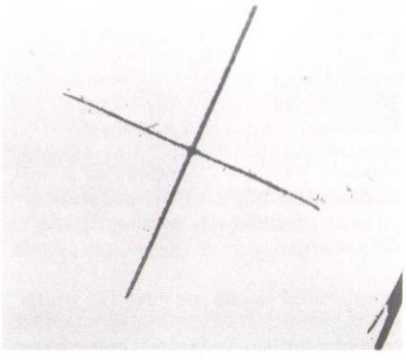
resist. While the electron probe may be focused down to atomic dimensions the ultimate resolution of the pattern is determined by electron scattering in both the resist and the substrate. If resist and substrate are both thin, so that relatively few scattering events occur as the electron passes through them, then pattern linewidths approach the 10nm target with centre-to-centre spacings of 40-50nm. These limits appear to be determined by the range of secondary electrons generated during resist exposure and by the size of the polymer molecule.

Multi-layer resists

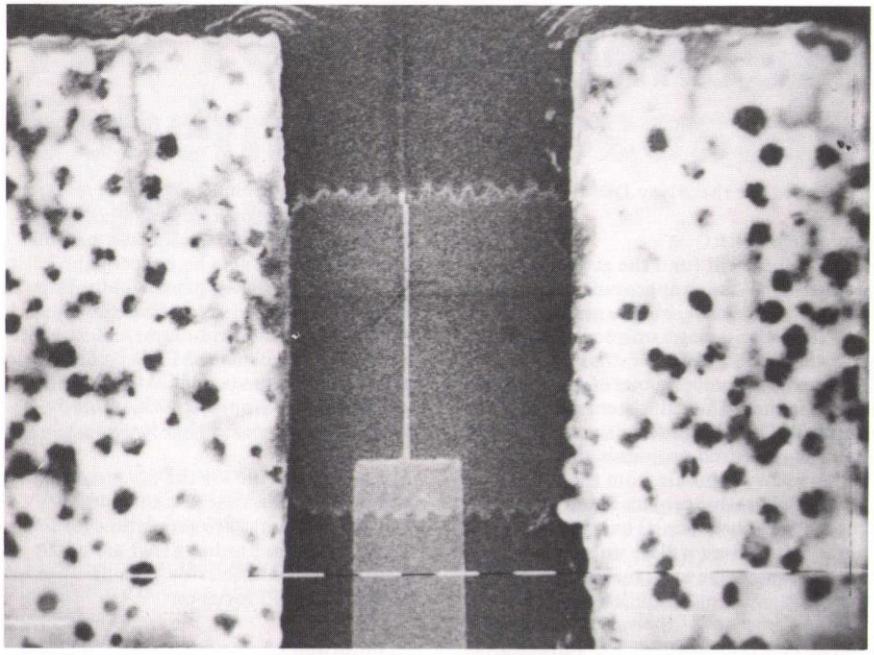
A thin resist layer cannot stencil deep patterns, so the requirement of very high resolution competes, for example, with the need for thick metal tracks to minimise electrical resistance. Some benefit can be obtained by using multi-layer resists. The system most used by the Glasgow group consists of two layers of PMMA differing slightly in sensitivity. This increases the aspect ratio (line width to line height) by a factor of two or so. Moreover, lift-off processing, in which the developed resist stencil is first overcoated with metal and then dissolved away, becomes much more reliable with this technique. Further improvements in aspect ratio require resists with greater mechanical strength and higher softening temperatures than PMMA-type polymers and this usually makes processing more complicated. We have experimented with silver-doped arsenic trisulphide glass overcoating polyimide as a possible solution to the problem. The glass is rendered insoluble in alkaline solutions when the electron beam drives silver from a thin top coating into the glass on exposure. The glass pattern then masks the underlying polyimide in an oxygen-reactive ion-etching step. Aspect ratios of 4:1 can be obained, testifying to the strength of polyimide, but resolution is disappointing. Despite hopes that the resolution of the apparently amorphous glass would not be determined by molecular size, there would appear to be sufficient structure in the glass to impose a 30nm linewidth limit.

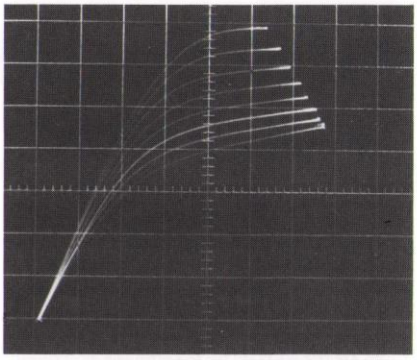
Very high resolution

The thin substrate requirement of very high resolution is another problem for the device engineer. Although some materials can be fabricated in thin-film form, it is not possible to do so for all materials of interest. We have shown, however, that 20nm lines can be written even on solid substrates and that, provided great precision is used in setting resist exposure, close-packed structures can be resolved in spite of the interactions which arise through scattering. We have also experimented with very soft (280eV) x-rays to replicate electron beam written masks on to solid substrates. While this technique has adequate ultimate resolution for this purpose, the effects of diffraction through the resist, the difficulties of making high contrast masks



Two crosses overlaying one another, written in separate lithographic steps following realignment of the specimen. Placement accuracy is 2-3nm; the lines themselves are 16nm wide.





Left: Scanning electron micrograph of a 75nm gate length GaAs MESFET written entirely by electron beam techniques. The gate is made of aluminium; source and drain contacts are of gold-germanium alloy.
Above: DC characteristics of the 75nm gate length MESFET.

by the e-beam step and the fragility of masks of adequate x-ray transparency all reduce resolution and conspire against the practicality of this approach. We believe that certain specialised applications can benefit from x-ray printing at the 0.1 micron level, but the flexibility of e-beam lithography confers a superiority which alternative techniques will find difficult to surpass. It remains true that the ultimate ultra-small structure is best fabricated on thin substrates and we expect to obtain our most interesting small device results using this approach.

Lithographic achievements

To put our lithographic achievements in perspective, state-of-the-art integrated circuit technology uses 1 micron minimum linewidths, so our structures are 100X smaller. The scope for investigating the effects of further miniaturisation is enormous and is of obvious significance to industry. In association with Plessey, RSRE and British Telecom we have started to fabricate FET structures in the 10nm to 1 micron gate length range. The smallest devices will be made on GaAs membranes, but development devices have already been tested on solid GaAs and Si substrates. Both GaAs and Si device technologies present interesting spatial resolution problems beyond the initial lithography. In silicon, for example, less than 100nm might separate implanted areas of material, and this separation must be preserved during the annealing step required to activate the implant. In GaAs, ohmic contacts to the source and drain on the FET are made by sintering Au-Ge-Ni alloys which are highly mobile. Novel heat treatment techniques will be needed to maintain sub-0.1 micron gaps in both these cases. Nevertheless, we have made workable 0.1 micron gate length Si MOSFETs and 0.075 micron gate length GaAs MESFETs, have measured their dc characteristics and are now considering how best to test these devices, whose switching speeds could well be less than 10ps.

Unique patttern writer

Yield is a major consideration when embarking upon a programme of device assessments. To date, all our patterns have been written with a converted Philips scanning electron microscope working at 50kV with an 8nm diameter electron probe. This instrument is capable of writing very few devices per day, all of which can be rendered useless by process failures or by a few minutes' careless testing. SERC funds will allow us to purchase a unique pattern writer operating at up to 100kV and forming 2nm diameter probes. This will be equipped with a high capacity stage to give us much greater throughput. The grant will also support the programme of device research and further development of lithographic techniques.

High-speed devices might well exhibit effects arising from the lack of carrier scattering events and the wave-nature of the electron. These will be most marked in the finest structures. Physicists have already begun to look for these phenomena, for example, in very narrow straight wires made by edge-shadowing techniques. Here the versatility of very high-resolution electron beam lithography comes into its own. One can, for example, test the electronic behaviour not only of straight wires, but also of very sharp (<10nm radius) bends and repeated meanders. One can look for evidence of ballistic transport between close-spaced electrons on semiconductor substrates.

A joint programme of research in these areas will soon commence between ourselves and Drs Lawrence Eaves and Peter Maine of the Department of Physics, Nottingham University, supported by an SERC grant. A further grant will finance an exploratory study of the positioning of biological material on patterned surfaces. This research will be undertaken jointly between ourselves and Professor Adam Curtis of the Cell Biology Department of Glasgow University.

Enormous scope

The scope for research arising from the development of ultra-small patterning techniques is enormous. Minimum linewidths amount to about 20 gold atoms. Positional accuracy is approximately 5 or 6 atoms. Coupled with advance deposition techniques such as Molecular Beam Epitaxy, materials can now be structured in three dimensions with almost atomic precision. What phenomena will the engineering community turn to its advantage with such unprecedented machining technology?

Dr S P Beaumont and Professor C D W Wilkinson

Department of Electronics and Electrical Engineering, Glasgow University.

Information technology

A progress report

Since it was established in September 1983, the Council's Information Technology Directorate, under its Director Dr D B Thomas, has been establishing the framework of the new programme. *SERC Bulletin* has already carried reports on certain aspects, including research in Intelligent Knowledge Based Systems (IKBS) and Support for Education and Training, both in the Autumn 1983 issue (Vol 2 No 9). There have been many new developments; this summary highlights the more important of them.

The Alvey Programme
The Alvey Programme is a collaborative research programme for the UK involving the joint efforts of industry, government and the universities. The programme is managed by the Alvey Directorate, based at Millbank, which coordinates the contributions of the various participants and in which SERC is represented. The programme will concentrate on precompetitive research in four main enabling technologies, namely IKBS, Software Engineering (SE), Man-Machine Interface (MMI) and Very Large Scale Integration (VLSI). There will also be substantial investment in Large Scale Demonstrator projects, in computing infrastructure and communications, and in education and training. Each area of research is the responsibility of a programme director; in each area a statement of strategy has been or is being prepared which will guide the allocation of funds to individual projects, which themselves will normally represent a collaboration between industrial companies and the academic sector. Progress in these various activities is reported regularly in *Alvey News*, published for the Alvey Directorate.

The role of SERC
The Council will fund the academic component of each approved collaborative research project or, in exceptional cases, will fund stand-alone university projects. It is important, however, that assessments of the various components of collaborative projects should be consistent with one another. This argues for a method of assessing research proposals as a whole, rather than proposals from the partners in a collaborative project being assessed piecemeal. The Council has therefore agreed that there will be no separate SERC committee structure in the Alvey area; instead, funding will be approved by the Directors of the various elements of the programme following a process which will involve consultation with advisory groups representing the community as a whole and to which academic members have been appointed by the Council.

The Programme
A strategy statement for IKBS has already been approved, and reference has already been made to the summary of the intended programme recently published in the *Bulletin*. SERC has agreed to accept particular responsibility on behalf of the Alvey Directorate for managerial support to the IKBS programme. Strategy statements for VLSI and Software Engineering have also been published and approved, and work on the MMI strategy statement is well advanced. Copies of the published strategy statements are available from the IEE. Summaries of progress on Large Demonstrator Projects and Infrastructure and Communications have been published in *Alvey News* number 2.

The VLSI programme will pursue research on individual process steps and techniques, including basic studies on materials and devices, and will also be concerned with the assembly of process steps into whole processes with tested process rules. There will also be a major investment in advanced CAD techniques and the development of CAD tools and languages. It is hoped to achieve one micron geometries within five years.

The starting point for the SE programme is the realisation that present *ad hoc* methods for software generation result all too often in products that are costly, inefficient and unreliable. The SE programme will focus on:

☐ improved quality: to develop methods to ensure that software achieves specific criteria relating to performance, reliability, security, on-schedule delivery and user requirements;

☐ improved productivity: to reduce costs, not only in the development of software but also in operation over its whole life-cycle, including maintenance and future evolution.

In the Large Scale Demonstrator programme, six projects have been approved to the project definition stage. The Infrastructure and Communications programme has embarked on an electronic mail service for programme participants. Discussions are also under way regarding a high performance test-bed network that could provide an Alvey Communications Environment (ACE) for those projects and services that require more advanced facilities than can be provided by the existing public networks.

Contact points

Intelligent Knowledge-Based Systems	Director for IKBS Dr D B Thomas	Alvey Directorate Millbank Tower Millbank London SW1 4QU 01-211 6108
Very Large Scale Integration	Director for VLSI Dr W Fawcett	Alvey Directorate 01-211 7866
Software Engineering	Director for SE Mr D Talbot	Alvey Directorate 01-211 0050
Man-Machine Interface	Director for MMI Mr C M Barrow	Alvey Directorate 01-211 5854
Large Scale Demonstrators	Director Mr S L H Clarke	Alvey Directorate 01-211 0299
Infrastructure and Communications	Director Mr D L A Barber	Alvey Directorate 01-211 5945

Information on SERC's role in the programme generally may be obtained from:

Dr D B Thomas	Director, SERC Central Office, Swindon	0793 26222 ext 2272
Dr M A Wilkins	Head of Secretariat Swindon	0793 26222 ext 2252
Dr D L Johns	Head of Education & Training, Swindon	0793 26222 ext 2105
Dr D M Worsnip	General advice on university participation in the programme	0793 26222 ext 2104

Copies of Strategy Statements and Alvey News may be obtained from Mrs Janet P Tomlinson, IEE, Savoy Place, London WC2R O8L.

The Teaching Company Scheme: a successful joint venture

The Teaching Company Scheme, supported jointly by SERC and the Department of Trade and Industry (DTI), which contribute equally to its funding, aims to develop active partnerships (Programmes) between universities* and manufacturing companies in order to:

☐ raise the level of manufacturing performance by effective use of academic knowledge and capacity;

☐ improve manufacturing methods by the effective implementation of advanced technology;

☐ encourage able graduates to train for careers in manufacturing;

☐ develop and retrain existing company and academic staff;

☐ give academic staff broad and direct involvement with industry to benefit research, and enhance the relevance of teaching.

An individual programme should contain three basic components: a company committed to a coherent set of significant improvements in its manufacturing practice; a university able and ready to contribute its knowledge to the implementation of such improvements; and a number of able young graduates (the Teaching Company Associates). In addition, some Programmes need support from 'Senior Assistants' whose main task is to take over some of the teaching and administrative duties of academic staff involved in Teaching Company work.

A key feature of any Programme is the function of the Associates as the 'working fluid' by which a large part of the technology transfer occurs. Expertise in the university is transferred to the company by the Associates who bring back to their academic departments an understanding and knowledge of the problems which arise in day-to-day industrial life. In order for this triangular arrangement to work at all appropriate levels of the company and the university, it is essential that relations should be established at a very senior (usually Managing Director/Professorial) level. Given commitment from the top, middle and junior management together provide an environment in which the Associates can function effectively. This interaction creates a permanent link between the university and company, with growing appreciation of each others' attitudes and skills. Eventually, traffic in knowledge and experience becomes a natural part of everyday life, possibly independent of any formal arrangement such as a Teaching Company Programme.

*In this article, 'universities' embraces both university and polytechnic departments.

The budget now stands at about £5 million a year, and it is hoped that this will rise to at least £11 million by 1988. Contributions from partner companies, already averaging 20% of total costs, are expected to rise to at least 33% in this period. The total number of programmes, now standing at about 140, should rise to over 200. The scheme is already operating outside its 'traditional' area of batch manufacture in mechanical engineering, with programmes in, for example civil and chemical engineering, biotechnology, plastics processing and electronics.

The following are just two examples of how successful a Teaching Company Programme can be.

Austin Rover/ Warwick University

At the Austin-Rover Common Lane plant, an integrated manufacturing system was installed in August 1981, to control the manufacture of light commercial (Sherpa) vans. The system is run from a mini-computer and the first schedules were implemented ten weeks after the project began.

In the first three months, the stock holding of sheet steel was cut from 1,700 tonnes to 400 tonnes as a result of the implementation of preferred sheet and gauge sizes. Total inventory holding has been reduced from £4 million to a little under £1 million.

Non-standard vehicle construction is now achieved in three weeks from the date of order, as opposed to 12-14 weeks before the installation of the system.

Material usage in each vehicle has been reduced through better allocation of steel and the planned use of component nesting, against standard sheet sizes. Average production of vehicles is 500 per week, resulting in annual savings of about £400,000. Total factory management systems have now been developed from this exercise.

Quite separately, a further initiative looked at the field stocks of vehicles. Due to the immense variety in specification, it was estimated that a field stock of 6,500 vehicles was required at an ex-factory valuation of £18 million. Derived from the integrated manufacturing system, a supplementary programme reduced the field stock to an optimum of only 226 vehicles. They comprise mainly fast-selling derivatives with the main system providing the slower selling derivatives in a period of six weeks maximum from placement of an order.

John Williams of Cardiff plc/UWIST

The Programme is based at John Williams Foundries Limited, a member of the John Williams of Cardiff plc group of companies, which has an annual turnover of £15 million and employs 400 people. The foundry supplies a full range of castings to the major diesel and heavy automotive manufacturers. For the past 20 years it has specialised in spheroidal graphite iron; current production is about 6000 tonnes per annum.

The Teaching Company grant of £24,000, which supports one Associate for two years, started in August 1983. The Programme is centred on reducing energy costs in the foundry, which consumes over 75% (£700,000 pa) of the energy used within the company. Total savings of 18% (£135,000 pa) have been achieved. Measures taken include:

☐ Improved regulation of coke supplies to cupolas;

☐ Improved ladle design, allowing a reduction in the amount of magnesium alloy used;

☐ Control of maximum electrical power demand, thereby avoiding peak charges;

☐ Improved design of furnace linings;

☐ Use of microprocessor control on an annealing furnace.

For details of all current programmes and further information on the scheme contact:

Teaching Company Directorate
SERC Central Office, Swindon (ext 2335).

Specially promoted programmes ...two profiles

Construction management

Construction management is concerned with the whole process of building structures efficiently. It involves both building and civil engineering and includes the needs of clients, design and planning contractual procedures, the organization and management of site operations, costs and productivity, and the use of computers in the construction process. The gross value of the UK construction industry's output in 1982 was £22½ billion, which represents approximately 11% of the gross domestic product. Hence any research which enables even a small improvement in the management and productivity of the construction industry will show significant potential cost savings to the community.

From the outset of the Specially Promoted Programme (SPP) in September 1981, the Programme's Steering Group has been concerned to achieve a balance in the programme between fundamental research and applied research. The Steering Group has, therefore, defined very clear objectives for the SPP, and the research community has accepted the challenge and is producing research that should ultimately benefit everyone.

The construction industry is highly fragmented and diverse with its output spread between many firms and specialisms including consultants, contractors, subcontractors and material suppliers. This has resulted in the industry being very conservative in its approach to taking up the products of research. However, since the SPP in Construction Management started in September 1981, it has been encouraging to note how members of the industry have responded to this SERC initiative. Considerable interest has been shown by companies and already research undertaken in the SPP is being taken up and applied within the industry in a variety of ways.

The SPP is concerned with both the design and the construction of structures. The process of designing and erecting a structure carries both technical and financial risks for the owner and the contractor. Project risks relate both to engineering and to the ability to build a project within the quoted price. Evaluation and management of risk are not well developed or widely used within the construction industry. Even the risk of work being delayed by exceptionally inclement weather has to be evaluated in order to avoid costly delays. Two research grants have been awarded to investigate methods by which risks and uncertainties can be identified and evaluated using operational research techniques. A computer-assisted construction project simulator allows users to model the activities on construction projects both at the design stage and during construction in order to understand the impact of a wide range of variables on both progress and resources (see front cover picture).

Understanding the influences on site productivity is seen as another important research area. A recent grant has been awarded to Heriot-Watt University to investigate design rationalization and site productivity. A modular coordinated design for a proposed building had been rationalized to ensure maximum productivity on site. The construction was monitored by observers using time-lapse photography and activity sampling techniques. Subsequent analysis of the data using a computer has shown that the design team's concept of 'buildability' was not realistic. Due to overlapping activities and the non-sequential nature of the work, only 60% of the site operatives' time was spent in making the building 'grow'.

At the present time there is not a clear understanding of how building designs can be rationalized to ensure ease of buildability on site. Further research grants have been awarded in this area to gain a fundamental understanding of the construction process.

In 1983, an initiative was taken to investigate why many construction management research projects undertaken over the past decade, despite capturing the interest and imagination of the industry, have not been implemented. The report highlighted many important aspects for future researchers. The implications are paradoxical: before industry can accept new ideas and research results it has to become more effective in operating its existing systems and practices. Only through improving these, and removing obvious short-term impediments, will it reach a situation where it can identify the major weaknesses in those systems and hence be prepared to seek and demand ideas for improvement and change. The report concluded that the implicit assumption of the 'complete researcher' with the ability to undertake fundamental research and to disseminate the findings to both the academic community and the construction industry needs revising. The report highlighted the need for more consideration to be given to the research/industry interface.

Some seminars have been held for academics and industrialists to disseminate research results. Further seminars are planned with the aim of improving the academic/industry interface.

For further information on the programme please contact: Professor W D Biggs or Dr R Flanagan, Joint Coordinators: Construction Management SPP, Department of Construction Management, University of Reading, Whiteknights, READING RG7 2BU; telephone Reading (0734) 875123.

Industrial robotics and ACME

Since Mr Peter Davey's resignation as coordinator of the Industrial Robotics Initiative in order to practise what he preached and set up his own sensor-guided robot company, **Dr Peter Smith** has been acting as interim coordinator. The activities of the programme are continuing as usual – indeed the Initiative is expanding as it heads for a challenging new phase. This Autumn, it will become part of the larger new directorate for the Application of Computing to Manufacturing Engineering ('ACME'), which is being set up in collaboration with the Department of Trade and Industry. The new directorate will bring two other Specially Promoted Programmes (Application of Numerical Control to Manufacture and Efficiency of Production Systems), as well as the coordinated programme in Computer-Aided Engineering, under the same umbrella with Industrial Robotics (see *SERC Bulletin* Vol 2 No 8, Summer 1983).

Combustion engines

The SPP in Combustion Engines Research began in January 1981. Although all aspects of reciprocating combustion engines research are included, it is primarily directed towards ground vehicular internal combustion engines. It is hoped that the programme will lead to significant improvement in fuel economy and to reduction in the noise and chemical emission levels in conventional petrol and diesel engines while maintaining performance.

To achieve this, research in particular topics has been encouraged, as well as collaboration between academic departments including disciplines other than mechanical engineering and with industry. Within the five year programme it is hoped that at least a three-fold increase in the level of support will be attained. Mr Lindsay Dawson promoted and coordinated the programme until his untimely death in November 1982. As reported in the last *Bulletin* Dr John Weaving, formerly of BL Technology, has been appointed as the new coordinator.

Mid-term review

A mid-term review of the SPP has recently taken place and, although it is too early to identify individual successes as a result of grants awarded within the SPP, there has been a marked increase in the level of support. Currently there are nearly 60 grants totalling more than £3.2 million spanning 26 academic institutions. Of particular note are the several instances of fundamental research being undertaken as essential underpinning for more applied industrial research. The work of Dr A D Gosman at Imperial College, London on computer prediction methods for flow, heat transfer and combustion is a good example of this. Also of note is the work of Mr N D Whitehouse of UMIST on combustion in quiescent direct injection diesel engines.

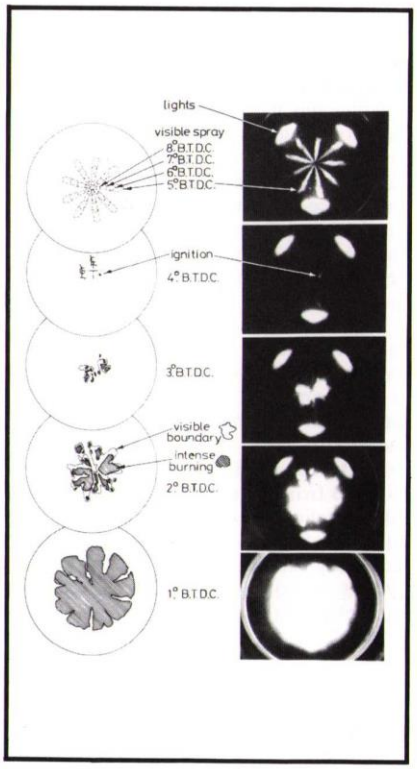
Close liaison with industry has been apparent in many of the grants including a growing portfolio of cooperative grants, currently ten, totalling about £0.5 million. Companies involved include BL Technology, Perkins, Lucas and Associated Engineering Ltd. The Programme has been less successful in attracting engineering departments other than mechanical engineering.

Priority topics

The response to the topics originally identified for particular attention has been varied but the majority are still considered of high priority. These are:

- small, high-speed, direct injection diesel engines
- lean-burn, high compression-ratio, high-turbulence, spark-ignition petrol engines
- direct-injection, spark-ignition engines
- combustion studies, particularly degraded and alternative fuels
- basic studies in automatic control and in particular transducers and actuators
- turbochargers and engine/turbomachinery interaction
- tribological aspects

Further applications on these topics and others within the programme would be very welcome especially where these are relevant to industrial needs and involve disciplines other than mechanical engineering. Those involving long-term original and speculative ideas are particularly welcome. Prospective applicants are invited to discuss proposals with Dr Weaving in advance. He may be contacted at: Poolhead, 150 Chessetts Wood Road, Lapworth, Solihull, West Midlands B94 6EN; telephone Lapworth (056 43) 2817, or contact Mr J E Farrow at SERC Central Office, (ext 2117).



Quiescent combustion chamber diesel combustion: SERC-supported research at UMIST. Sketches (left) give greater detail deduced by inspection of the high speed camera frames (right), using a photograph analyser.

Rolls-Royce/SERC cofunding agreement

An agreement was made last year between SERC and Rolls-Royce for the joint support of a programme of research into gas turbine and related technologies. By adopting a joint approach it is hoped to make more effective use of Rolls-Royce and SERC resources and to provide a valuable mechanism for enhancing the industrial relevance of SERC-supported research.

The programme of research includes combustors, compressors and fans, turbine aerodynamics and cooling, vibration and engine dynamics and materials. However, to concentrate the resources available, priority is being given to work on the use of ceramics and mechanical transmissions.

The basis of support is through the cooperative grants scheme and up to £375,000 commitment per annum by SERC is assigned to the programme over the next three years. Prospective applicants are invited to discuss proposals with either Dr M D Fox of Rolls-Royce Ltd, PO Box 3, Filton, Bristol BS12 7QE; telephone Bristol (0272) 693871 or the SERC coordinator Mr L Airey, 72 Pierrefondes Avenue, Cove, Farnborough, Hants; telephone Farnborough (0252) 541989. The appropriate contact at SERC Central Office, Swindon, is Mr J E Farrow (ext 2117).

The Science Board strategy for support of core science

The Science Board has recently submitted to Council a statement of its strategy for support of core science. This statement has been circulated widely for information and comment to all heads of science departments in universities and polytechnics and a summary is given below. Copies of the document are available on request from C R Simmons at SERC Central Office, Swindon (ext 2314).

The Science Board supports a scientific community of about 12,000. Its remit covers a broad sweep from biology[1] through chemistry and physics[2] to mathematics. These are the 'core' sciences on which much of the nation's outstanding scientific reputation has been built; they underpin the activities of all the other science-based research councils, and of the science-based industries of the nation, on which our future prosperity depends. The Board also funds the training of a large proportion of the basic scientists needed.

The size and diversity of the community and the nature of science make it difficult to devise and implement a detailed plan for core science; indeed overplanning is undesirable lest it stifle new initiatives. Nevertheless, the Board moved during 1982-83 from a passive to a more active role. It believes this is required in the interests of core science, despite the increasing need to be more selective as a result of shortage of money. The Board also believes it is now timely to set out its developing strategy.

Components of the strategy

The Board's strategy has a number of key components:

☐ allocation of funds to particular subjects to ensure the vitality of each of the core sciences;

☐ identification of research themes within subjects, together with a continuing review of the balance of support between these themes;

☐ adequate support of 'blue-sky research' proposed by individual scientists;

☐ recognition of the importance of multidisciplinary research, including the establishment of special initiatives where necessary;

☐ enabling its community to gain access to expensive central facilities that are necessary for front-line research in many areas of science;

☐ providing postgraduate studentships to enable well-qualified graduates to obtain training in methods of research and thereby also contributing to the total research effort, or to obtain advanced training in topics relevant to their future employment.

Professor John Cadogen FRS

Currently, the Board allocates its resources roughly equally between research grants, the central facilities, and studentships. It is convinced that reduction of the absolute amounts available to these sectors would irreversibly damage the nation's core science capability. If new money became available the Board would allocate this in order of priority to grants, closely followed by studentships, with facilities third.

Allocation of funds for research grants

Until 1982-83, the Board did not allocate grants to each core science; instead funds were distributed on the basis of the value of 'alpha' grant applications received by each committee. This method did not allow the Board to exercise its judgment on the balance of support which should be allocated to the different competing disciplines. In the 1982-83 session it introduced a system whereby it determined, at the start of the session, how much money should be made available to each committee. It has already used this mechanism to provide some, albeit small, revitalisation of physics and mathematics and it will continue to monitor developments and, if necessary, take further action to ensure as healthy a level of activity as possible.

Research themes

As a crucial element in its strategy, the Board has asked each of its committees to identify essential research themes; the classification is not intended to be comprehensive; it is not unique and will evolve with time. The analysis of the Board's 1982-83 grant commitment by research themes is given opposite. Detailed accounts of the themes are available and each committee will be refining these with its scientific community. The outcome is expected to be progressively reflected in the grant awarding procedure during 1984 and later years.

The Board and its committees will regularly review the identified research areas. Any imbalance in the level of support of these areas will be identified and, if necessary, corrective measures will be taken. The analyses are revealing more general requirements such as inadequate access to advanced instrumentation. Inevitably some committees' themes include areas of interest to other research councils (such as molecular biology). Analyses of these areas will be in collaboration with the council concerned and take account of support given by both bodies.

Work on the research of the themes is crucial to underpinning the science-based sectors of the economy. Although it is not the Board's intent to support research specifically for industry, it believes that it must support core science in such a way that British industry prospers.

Multidisciplinary research

The Board is convinced of the importance of multidisciplinary activities and has recently recognised the need for support

1. Excluding those applied aspects supported by the Agricultural and Food, Medical and Natural Environment Research Councils.
2. But not astronomy and space research or nuclear physics.

of new programmes in low dimensional structures, protein engineering and chemical sensors; it believes that other multidisciplinary proposals will emerge from the community. The Board recognises that its central facilities also promote multidisciplinary research.

The Board, at this stage, does not propose to set aside a special fund for the support of individual multidisciplinary research projects. It will however look at programmes on their merits recognising that some will require additional funding and specially convened panels of the Board for their assessment.

'Blue sky' research

Although becoming more 'dirigiste', the Board will always ensure that adequate funds must be available to support outstanding scientists working in any area on problems of excellence, timeliness and promise. Indeed the Board recognises that most breakthroughs result solely from the insight of exceptional scientists pursuing understanding for its own sake.

Finale

The Board believes that its strategy for the support of core science will allow it to determine more precisely its need for funds for the support of research and ensure the most cost-effective use of such funds as it has. The analysis within the various components will continue and new areas and emphases will emerge. Science also will change and the Board will do its best to ensure that the necessary funds are available to support the exciting new developments.

John Cadogan

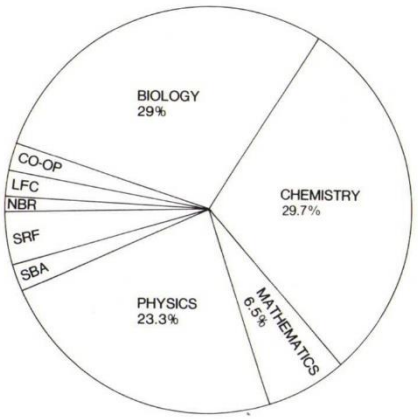
Professor J I G Cadogan FRS is Research Director of BP Plc and Chairman of the Science Board.

ANALYSIS OF 1982/83 GRANT COMMITMENT BY RESEARCH THEMES: % OF BOARD COMMITMENT

BIOLOGY
Genes & Biological Engineering 5%
Microbes: The Invisible Workforce 3.8%
Plant Science & Productivity 3.2%
Animal Cell Diversity & Development 3.5%
Neurobiology 1.5%
Cognitive Science 1.2%
Animal Function 3.5%
Biological Molecules: Structure, Function & Engineering 7.3%

OTHER SUBJECTS
Co-operative Research Grants 2.3%
Laser Facility 1.9%
Neutron Beam Research 1.1%
Synchrotron Radiation Facility 4.3%
Science Based Archaeology 1.9%

PHYSICS
Novel Instruments 0.2%
Low Dimensional Structures 0.8%
Surfaces & Interfaces 1.9%
Advanced Semi-conductor Physics 1.8%
Physics of Materials 3.3%
Quantum Fluids 1.5%
Amorphous Materials 1.7%
Electronic Structure of Metals & Alloys 3.1%
Magnetism in Metals 1.0%
Computer Simulation 1.1%
Plasma Physics 0.6%
Development of New Lasers 1.9%
Atomic Collision Processes 4.4%



CHEMISTRY
Instrumental Techniques, Analysis & Sensors 4.3%
Energy Conversion & Storage 0.7%
Surface Science, Colloids & Heterogeneous Catalysis 2.9%
Reaction Mechanisms, Dynamics & Catalysis 7.7%
Synthesis, New Molecules & Methods 3.8%
Biological, Medicinal & Pharmaceutical Chemistry 4.4%
Structure & Bonding 5.3%
New Materials 0.6%

MATHEMATICS
Stochastic Modelling 1.1%
Mathematical Biology 0.7%
Non-Linear Systems 0.3%
Mechanics of Continuous Media 1.5%
Theoretical Physics 0.3%
Numerical Analysis 0.6%
Mathematical Analysis 0.3%
Geometry & Algebra 1.6%
Operational Research 0.1%

Short courses in science subjects

• The Physics Committee is sponsoring two short courses during 1984.

The first, entitled **Characterisation of semiconductor materials**, will be held at St Andrews University from 26 June to 12 July and will cater for up to 60 participants.

The course is intended primarily for first and second year research students and priority will be given to SERC students for whom the course will be free. The course will also be open to more senior academics and participants from industry.

Further details and application forms may be obtained from the course director, Professor R A Stradling, Department of Physics, University of St Andrews, North Haugh, St Andrews, KY16 9SS. telephone St Andrews (0334) 76161.

The second course is entitled **Theoretical condensed matter physics** and is to be held at Oxford University from 17 September to 28 September; it will cater for about 50 participants.

As with the St Andrews course, the subject matter is intended for first and second year research students, priority being given to those holding SERC awards, and whose attendance at the course will be paid for by the Council.

Further details and application forms may be obtained from the course director, Dr G A Gehring, Department of Theoretical Physics, University of Oxford, 1 Keble Road, Oxford, OX1 3NP; telephone Oxford (0865) 53281.

• The Science-based Archaeology Committee is sponsoring a short course on **Dendrochronology and radiocarbon calibration** to be held at the Field Centre of the Queen's University of Belfast at Dundrum, Co Down, from 3 to 7 September 1984.

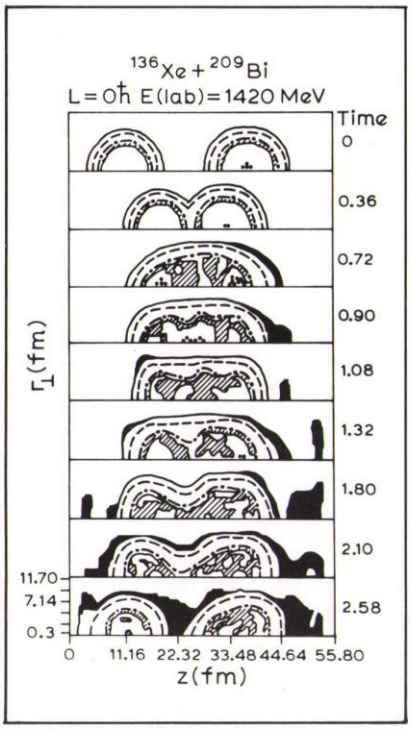
The course, for up to 40 participants, is intended primarily for first or second year research students, but will also be open to more senior academic personnel. Priority will be given to SERC students, for whom SERC will pay the full cost.

Further details and application forms to attend may be obtained from the course director, Dr M G L Baillie, Palaeoecology Centre, Queen's University of Belfast, University Road, Belfast, Northern Ireland BT7 1NN; tel: Belfast (0232) 245133.

Scientific computing on the Cray at Daresbury

The Cray-1 computer arrived at Daresbury in 1979, and over the last four years it has led to significant advances in many areas of computational science ranging from nuclear physics to astrophysics. As described in a previous article (*SERC Bulletin* vol 2 no 3, Autumn 1981), the Cray-1 is a vector processor, about an order of magnitude faster than the most powerful computers previously available to the UK academic community. It gains this increase in speed by using a high performance memory linked to pipelined functional units, which can be driven at maximal rate when in vector mode.

About 100 different groups gained time on the Cray during the 3½ years it was at Daresbury, by application and peer review. Most of the grants for time were in the Science Board area, but there was also substantial involvement of the other SERC boards, as well as the Natural Environment Research Council for oceanographic studies.



Contour plots of the time-dependent density of a ^{136}Xe nucleus colliding with a ^{209}Bi nucleus, at an energy of 1420 MeV. Successive figures are snapshots of the density at times given in units of 10^{-21} s. The black region corresponds to the density of 'promptly-emitted' nucleons.

Many of the numerical techniques used in computational science are common to several subject areas. As an example, in many physics and engineering applications it is necessary to solve the partial differential equations for a field over a spatial and temporal mesh – in hydrodynamics, plasma physics, electromagnetism and so on. The use of a powerful computer may be necessary to treat all three spatial dimensions, and permits a finer mesh size to be used for studying fine structure in the solutions. There are also many problems which can be studied by simulation techniques, in which the equations of motion of a large number of particles coupled by their mutual interaction are integrated in discrete time-steps. A powerful computer enables a larger number of particles to be studied, thereby reducing statistical noise effects. The Cray has been used for simulation studies in plasma physics for following the equations of motion of charged particles in electromagnetic fields, astrophysics for studying the motion of stars in their mutual gravitational field, and molecular dynamics for calculating the statistical mechanics of atoms and molecules in liquids and solids. In the plasma work typically 10^5 particles are considered, and a group from Bangor have simulated the interaction of laser beams with plasma targets, observing nonlinear effects like the filamentation of the plasma which have been observed experimentally.

Nuclear collisions

The Time-Dependent Hartree-Fock method is widely used in nuclear physics for studying the time-evolution of a many-body system such as two nuclei colliding, and provides a good example of the solution of partial differential equations over a spatial and temporal mesh. In this case the one particle wavefunctions of the nucleons in the many-body Slater determinant wavefunction obey a time-dependent Schrödinger equation, moving in the potential field due to the other nucleons. In a typical application to a nuclear collision, 100 or so single-particle wavefunctions have to be calculated, each wavefunction being evaluated over a spatial mesh which must be large enough to contain the separated, non-interacting nuclei; as a compound nucleus may form in the collision, a large number of time-steps is usually necessary for solving the Schrödinger equation. Clearly this is an enormous computing task, and before the advent of the Cray-1 it was hardly possible; even with the Cray it is usually necessary to reduce the problem to two spatial dimensions, by making use of axial symmetry in head-on collisions, or suitable approximations for finite values of the impact parameter. An example of the nuclear reactions which have been studied using this technique by theorists at Manchester and Daresbury is the collision of ^{136}Xe nuclei with ^{209}Bi (see figure). It was found that when the Xe nucleus had a kinetic energy of 1420 MeV, particles were transferred from the lighter to the heavier nucleus in the course of the collision. This is anomalous and surprising behaviour, but it explains the experimental observations on this system for the first time.

The partial differential equations which occur in quantum mechanics are usually solved in a time-independent framework, making use of a basis set representation of the wavefunctions so that they become matrix equations. The determination of eigenvalues and eigenvectors, matrix inversion and multiplication then become important, and the Cray has enabled large systems to be studied in detail. In quantum chemistry the use of the vector processor, hand in hand with advances in technique, has made it possible to study the geometry and energy of molecules of pharmacological interest, and potential energy surfaces in chemical reactions can also be studied to an accuracy hitherto unknown.

The R-matrix method

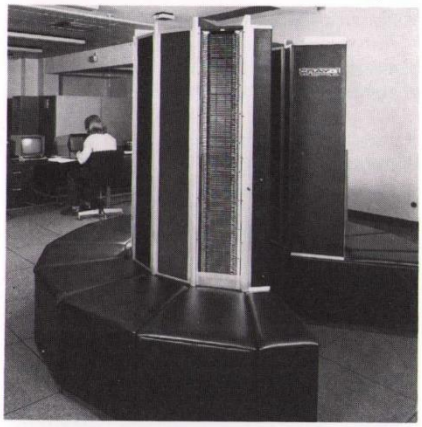
Like quantum chemistry, the interaction of electrons and photons with atoms is a many-body problem, and powerful techniques have been developed in recent years for tackling these problems in which at least one electron has enough energy to leave the atom; one of the most widely used techniques is the R-matrix method, largely developed by the Belfast group, in which the solution of the Schrödinger equation in a strongly interacting region close to the atom (usually treated in a basis set representation) is matched on to an asymptotic scattering region. With the Cray it was possible to study atoms containing more electrons, and as an example the Belfast and Daresbury groups could study electron excitation processes of Si ions, very important for studies of the solar atmosphere. An atomic calculation which was quite impractical before the advent of the

Cray-1 was a study of the hydrogen atom in a magnetic field carried out by theorists at Daresbury. This problem is particularly difficult, as the spherically symmetric electric field due to the proton at the centre of the atom goes over to a cylindrically symmetric magnetic field away from the atom, making it awkward to choose appropriate basis functions for the electronic wavefunctions. The results of this calculation explain structure in the spectrum (seen in experiments on Ba, Sr etc) in terms of localization of the electronic wavefunction which could not be predicted on classical arguments; the results are significant for general theories of the quantum motion of particles in fields.

Condensed matter physics

In condensed matter physics recent theoretical advances have made it possible to solve the electronic Schrödinger equation accurately in complicated materials like alloys, and at surfaces. It is even possible now to calculate interatomic forces, leading to an understanding of crystal stability, phase transformations and defect properties. But this work is very demanding computationally, as a large basis set is necessary to represent the electronic wavefunctions accurately, and the wavefunctions must themselves be determined at a large number of wavevectors in the Brillouin zone. The electrons move in a potential field determined self-consistently, and many iterations are usually necessary to obtain self-consistency. The power of the Cray makes it much easier to carry out bigger (and therefore more realistic) calculations than ever before; such calculations would simply not get done on a conventional machine. But using the Cray, self-consistent band structure calculations were almost routinely carried out in Cambridge and elsewhere on materials like the transition metal dichalcogenide layer compounds, which have remarkable electronic properties. The Bristol and Cambridge solid state theory groups carried out a particularly interesting calculation on the magnetic properties of the ferromagnetic metals iron and nickel above the transition temperature, at which the macroscopic magnetism disappears. The calculations showed that microscopic magnetic moments do persist above this temperature, but with randomised orientation; this has turned out to be a key step in resolving the long-standing puzzle about the nature of magnetism in metals with itinerant electrons.

To extract the maximum information from many solid state spectroscopies such as Low Energy Electron Diffraction and X-ray Absorption Near-Edge Structure it is necessary to calculate the spectrum assuming a particular atomic geometry, and then adjust the geometry until optimum agreement with experiment is obtained. Advanced techniques of multiple scattering theory are used to solve the Schrödinger equation for the diffracted electrons in LEED, or the excited electrons in XANES, but it is still very time-consuming computationally and involves a great deal of matrix manipulation. The use of the Cray greatly facilitates the determination of atomic geometry from XANES spectra, which is otherwise extremely time-consuming, and in this way groups from Daresbury and Rome were able to extract more information about the detailed coordination geometry around the oxygen-binding site in haemoglobin. This is needed to understand the energetics of binding and releasing oxygen in this vital molecule.



The Cray-1 at Daresbury

Flexibility

The range of exciting new science which was carried out on the Cray during its first few active years at Daresbury was immense: major advances were made in protein crystallography, in modelling the atmosphere, studies of phase transitions and so on.* One of the features of the Cray is its flexibility, with both scalar and vector processing capability, and this contributed considerably to its rapid acceptance by the computational science community as a valuable new tool. Not only did it make possible calculations which would never have been undertaken on a scalar machine, but it also made people think about completely new ways of tackling problems – brand new methods and algorithms were developed in quantum chemistry, atomic physics and doubtless other areas.

On 5 May 1983, the Cray closed down at Daresbury, but as the major computer at the University of London Computer Centre it will serve the academic community for years to come. But even with the Cray-1 some problems are intractable due to time or memory limitations – the third spatial dimension has still to be neglected in many simulation studies, and accurate studies of chemical reactions are not yet possible. For these we must wait for the next generation of computers.

Dr John Inglesfield
Head – Theory and Computational Science Division Daresbury Laboratory

*Further information is available in the *Theory and Computational Science Appendix to the Daresbury Annual Report 1982/83*

Use of vector processors at national centres

In June 1983 the Cray-1 S/1000 computer was moved from the Council's Daresbury Laboratory to the University of London Computer Centre to serve as a general purpose machine for use by the academic community. In parallel the Computer Board decided to equip its other national centre at Manchester with a CDC Cyber 205. In order to provide continuity for their work, existing SERC users of the Cray continue to have free access to this machine until July 1984.

The Council has now agreed that the cost of accessing vector processors at both the Computer Board's national centres, should, *in exceptional cases,* be an admissable charge against SERC research grants, for the interim period 1 August 1984 to 31 July 1985 only. It is expected that users should bid for an allocation of time through their institutions in accordance with the normal mechanism for use of national centre computers. SERC's support, which will be limited to vector processing charges levied by national centres and will not include front end processor charges, will only be given for major use of vector processors and applications will be subject to the normal peer review procedures.

Further details of this decision were notified to institutions by letter RG 6/84 on 9 February 1984. Any enquiries on this subject should be directed to the appropriate Committee Secretariat or to Mr R G Tidmarsh at SERC Central Office, Swindon (ext 2179).

Organometallic che

Research into the molecular

One of the most exciting areas in chemistry currently is the application of the ideas of organo-transition metal chemistry to new types of catalytic systems. The d-block transition metals comprise some 24 elements. Some of the (chemically) most remarkable compounds are those formed by the union of d-metals and an organic group (ligand). One type of binding, π-bonding, allows for example the stabilisation, in a metal complex, of organic ligands which are themselves quite unstable in the free state. Another sort of binding, involving sigma bonds from the metal to the organic ligands, is more conventional in appearance but the reactivity of species containing such bonds is often very high. This leads to important and useful properties, for example in catalysis.

Catalysis is of immense importance and virtually the whole chemicals industry is built on its applications. A catalyst causes a chemical reaction to proceed more quickly and, equally important, more specifically, with fewer by-products, than it would without. Industrially the most prevelant types of catalysts are based on metals or metal oxides. They are more robust than biological catalysts and more suitable for large-scale manufacturing plants. The metals that they are based on are usually d-block transition metals, and within that group there are six, the platinum metals, which have even higher than average activity.

Of these, particularly high chemical activity is found for rhodium, palladium and ruthenium. The metals are expensive because they are rare and useful but, since little catalyst is needed as it is always recycled, the economic advantages in running costs of using platinum metal catalysts far outweighs the extra initial cost.

Most catalysts in industrial use today are *heterogeneous*. They are based on reactions occurring at metal surfaces in two-phase (eg gas-solid) systems. These are rather effective for a wide variety of transformations but their study has proved extremely complex and even today much of what is known about their modes of action is based upon analogies to the transformations undergone by homogeneous (ie soluble) metal complexes. Since soluble metal complexes are single, discrete substances, often crystalline, they can be relatively easily and completely characterised by a variety of techniques, including x-ray and neutron diffraction and various forms of spectroscopy.

Such soluble complexes are not only important as models for surfaces but can also act as very effective *homogeneous* catalysts in their own right. Indeed, they often display higher reactivity and greater selectivity than the analogous surface catalysed reaction. These reactions are also much easier to study and the mechanisms by which they act can relatively readily be uncovered.

An important area of work in Inorganic Chemistry at Sheffield has for a number of years been concerned with the development of the organometallic chemistry of rhodium, ruthenium and palladium. This has been particularly aimed at the development of new types of complexes, frequently with special types of π-bonded ligands, which are then capable of effecting novel and interesting types of transformations of use to industry.

Such a development has been the pentamethylcyclopentadienyl ligand which when joined to rhodium or iridium confers certain unusual properties on the metals. One is an uncharacteristic affinity for oxygen-containing ligands (figure 1),

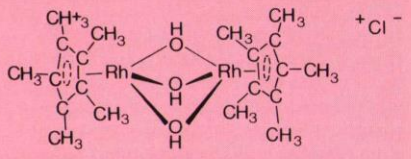


Figure 1 $\left[(C_5\,Me_5\,Rh)_2\,(OH)_3\right]Cl$

another is the ability to stabilise abnormally high oxidation states. One of the most typical properties of rhodium (and also other platinum metals) is the ability to transfer hydrogen from one organic compound to another (or from H_2 itself to organic compounds). This property is still retained by our pentamethylcyclopentadienyl rhodium compexes (and also by some closely related benzene ruthenium complexes) which have been found to catalyse the following useful reaction in which acetaldehyde is converted into ethanol and acetic acid by the route shown in figure 2:

$$2CH_3CHO + H_2O = CH_3CH_2OH + CH_3COOH$$

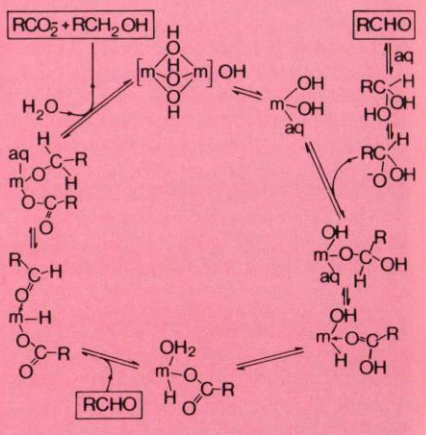


Figure 2 (m = C_5Me_5Rh; R = CH_3)

Another reaction involving the transfer of hydrogen is the rather unusual synthesis of unsaturated silicon compounds (used in the synthesis of natural products) directly from the olefin and a silicon hydride,

Checking products from methanol reactions by gas chromatography are (left to right): Professor P M Maitlis, undergraduate A Bushell and CASE postgraduate student T A Smith.

mistry and catalysis

basis of catalysis at Sheffield

$$2RCH{=}CH_2 + R^1{}_3SiH = RCH{=}CH\text{-}SiR^1{}_3 + RCH_2CH_3$$

The mechanisms of these reactions have been investigated and shown to proceed by the intermediacy of metal hydrides.

In connection with this last work a very novel complex of rhodium in the unusually high oxidation state of +5 (figure 3) was

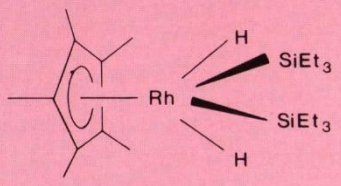


Figure 3

isolated. Preliminary characterisation was largely by NMR spectroscopy. This has more recently been confirmed by x-ray and low temperature neutron diffraction studies.

There has been considerable interest in the reduction of benzene; of the various products which can be formed, cyclohexene would be much more useful than cyclohexane. However, no attractive route for this transformation has been available. In a CASE project with ICI, we have shown that benzene complexed to pentamethylcyclopentadienyl-iridium (where the complex carries a dipositive charge) is readily attacked by two hydrides to give the neutral cyclohexadiene iridium complex. This in turn is readily attacked by two protons to give free cyclohexene, the desired product. If the protonation is carried out in benzene then the starting complex is regenerated and the cycle completed (figure 4). Thus, benzene is reduced to

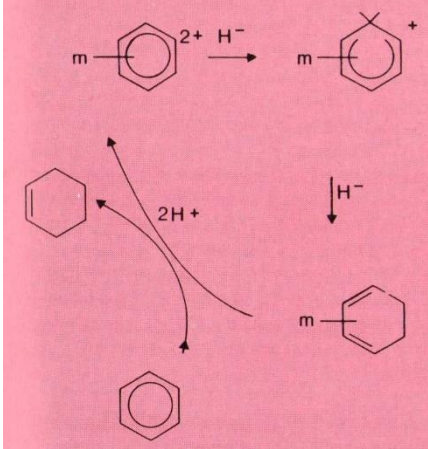


Figure 4 [m = C_5Me_5Ir]

cyclohexene by the sequential addition of two hydrides and two protons.

Methanol is now a relatively cheap and very plentiful commodity chemical and one problem that we are investigating is what can it be used for in simple transformations. One such reaction is the transfer of hydrogen to organic acceptor molecules; for example cyclohexanone can be efficiently hydrogenated to cyclohexanol using methanol and a metal complex catalyst. The other product is another useful chemical, methyl formate. A number of metal complexes are active for such transformations including the rhodium complex in figure 1:

$$2CH_3OH = CH_3OOCH + 4'H'$$

The further potential of this reaction can be gauged from the possibility of isomerising methyl formate into acetic acid,

$$CH_3OOCH = CH_3COOH$$

which would yield a route from methanol to acetic acid requiring no extra carbon monoxide.

The alternative route from methanol to acetic acid with carbon monoxide,

$$CH_3OH + CO = CH_3COOH$$

is now a very important commercial process using a rhodium-carbonyl iodide catalyst.

We have recently begun a mechanistic study of the closely related reaction in which methyl acetate is converted into acetic anhydride,

$$CH_3COOCH_3 + CO = CH_3CO.O.OCCH_3$$

Commercial operation requires the use of various promoters, in particular organic bases. We have shown how and why these promoters work and it is now possible to design new catalyst systems more rationally for this reaction. Both these two projects have been on CASE awards.

We have also used some of our complexes to model metal surfaces and the reactions that occur there. In one recent experiment we were able to show, by NMR spectroscopy on an isolated complex, that alkyl groups can readily migrate between two metals atoms in a single molecule (figure 5). This promises to be

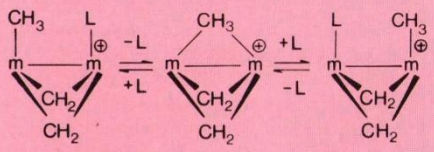


Figure 5 [m = C_5Me_5Rh; L = CH_3CN]

useful in understanding how some of the transformations of hydrocarbons that occur on platinum surfaces during petroleum refining ('reforming') take place.

Peter Maitlis FRS
Professor of Inorganic Chemistry, Sheffield University

Using the SERC High Field NMR Service in Sheffield is Dr C M Spencer with Professor Maitlis (left) and Dr B E Mann, in charge of the service.

First year's experiments on the NSF

The NSF has now completed its first year of fully scheduled operation. During this time 38 experiments have taken beam time using 24 different accelerated beam species and terminal potentials up to the initial design voltage of 20 MV. Already many interesting and important new results have been obtained and reported in the literature and at international conferences.

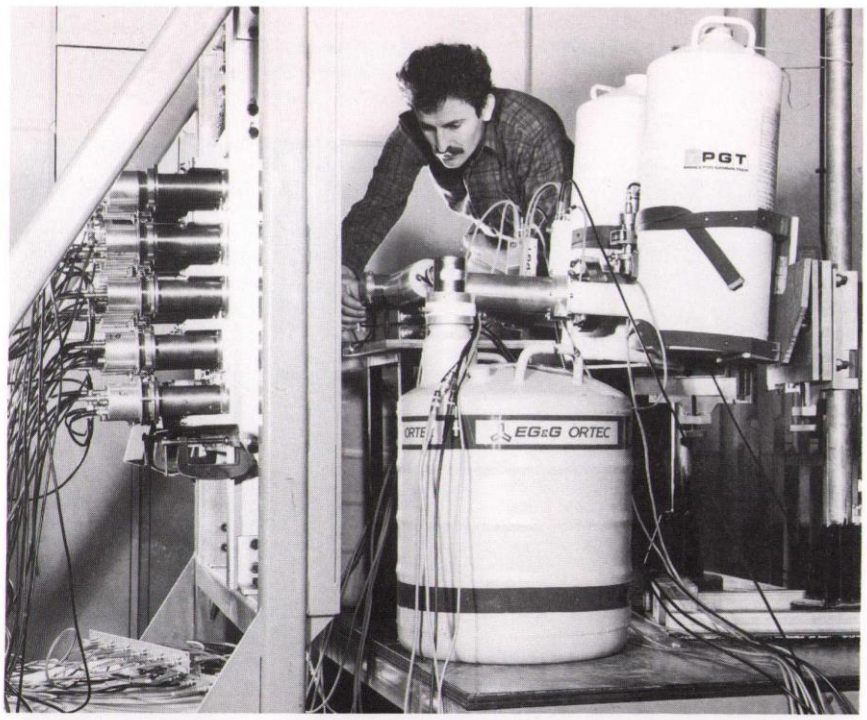
A major part of the experimental programme has been devoted to studies, by groups from Liverpool and Manchester Universities, the Niels Bohr Institute, Copenhagen and Daresbury Laboratory, of gamma-ray cascades emitted by nuclei created in heavy ion collisions. Important developments aiding this work have been the total energy suppression-shield array (TESSA) and the neutron detector wall. Both are unique pieces of equipment used to investigate rapidly rotating nuclei in the case of TESSA and nuclei very deficient in neutrons in the case of the wall. Recent discoveries have included the observation of a major reduction of nuclear pairing at high rotational frequencies. A transition is observed from the rotation of the nuclear superfluid to that akin to the rotation of a solid body. In the recently discovered region of high deformation near mass 80, record high rates of rotation have been observed and some nuclei in this region then behave remarkably like rigid rotors. Also at high frequencies evidence has come to light of a major shape change in the nucleus – the onset of super-deformation. The nucleus takes the form of an ellipsoid with major to minor axis ratio of 2:1 just before it fissions due to the rotational stresses.

Important work has also been done with the scattering chamber and the high resolution magnetic spectrometer by groups from Birmingham, Edinburgh, Oxford, London (King's College) and Bradford Universities and Daresbury. For example direct nuclear break-up of a projectile nucleus at the surface of a target nucleus has been observed for the first time. A new technique called Resonant Particle Spectroscopy has also been developed. By kinematic reconstruction of projectile break-up fragments, spectroscopic information of unbound high spin cluster states in nuclei formed in heavy ion reactions is being deduced.

In a non-nuclear experiment a group from Harwell have taken very accurate measurements of the energy loss of heavy ions as they pass through thin foils by using the magnetic spectrometer in a novel way. They have obtained new, and as yet unexplained, results on the electronic stopping of energetic ions in solid materials.

Finally in November 1983 the unique combination of dilution refrigerator coupled to the isotope separator in turn coupled to the tandem accelerator was used by groups from Oxford, Sussex and Manchester Universities and Daresbury. Radioactive nuclei produced in a reaction were separated according to their mass by the isotope separator and implanted in the refrigerator at a temperature of 20 mK. This enabled the magnetic moment and electromagnetic properties of the daughter nuclei from the decay to be measured.

Dr H G Price
NSF Division, Daresbury Laboratory



The neutron detector array and associated gamma-ray detectors.

Rutherford prize shared by theorists

The 1984 Rutherford Medal and Prize have been awarded jointly to Professor P W Higgs (Edinburgh University) and Professor T W B Kibble (Imperial College, London).

The discovery in 1983 of the massive W and Z bosons at CERN (see *SERC Bulletin* Vol 2 Nos 8 and 9 Summer and Autumn 1983) has provided striking evidence for the Glashow-Salam-Weinberg unified gauge theory of electromagnetic and weak interactions. The key idea used in the construction of the 'electroweak' theory was that of spontaneous symmetry breaking in gauge theories, which was developed mainly by Higgs and Kibble in the mid-1960s.

The experimental implications of the idea, the 'Higgs-Kibble mechanism', were realised by the Nobel laureates Salam and Weinberg. The particles whose existence is predicted by the idea are called 'Higgs particles' – another measure of the importance attached to the work. Higgs' and Kibble's work has formed the basis for the most important developments in elementary particle physics of recent years.

Professor Kibble is currently a member of SERC's Nuclear Physics Board and chairs its Theory Sub-Committee.

ALEPH detector for LEP

Construction of LEP, the new European electron-positron collider at CERN, scheduled to come into operation in 1989, is well under way.

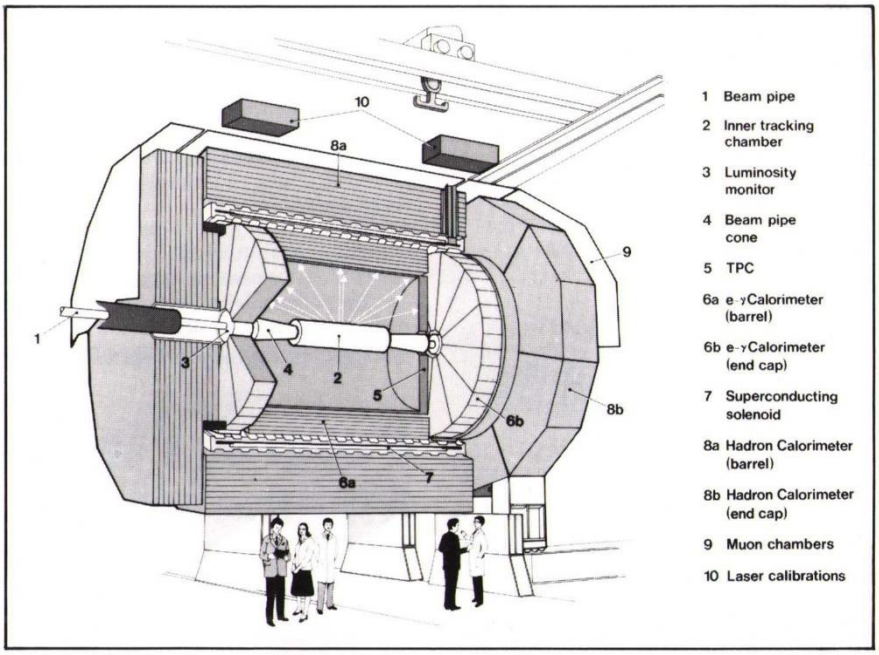
Meanwhile, in CERN's member states, the development of the new generation of detectors needed to exploit LEP has started. The UK is involved in three of the four approved experiments: ALEPH, DELPHI and OPAL. All are large international collaborations with several hundred participants, not just from Europe but also from Japan, China, Canada, USSR and USA.

The ALEPH detector aims at sophisticated simplicity: sophisticated in that each component of the detector is designed to extract the maximum possible information, simple in that the number of different components is at an irreducible minimum. The drawing shows that ALEPH consists of only four major items: an inner tracking chamber, a time projection chamber (TPC) an electromagnetic calorimeter, and a hadron calorimeter, all built inside or around a superconducting solenoid magnet with a field of 1.5 Tesla.

The structure is therefore rather homogeneous: all particles coming from the interaction region go through the same combination of detector elements, with very few 'holes' or dead regions. The TPC measures the momentum and position of tracks, and by energy loss measurements distinguishes the type of particle. The electromagnetic calorimeter measures the energy of electrons and photons, and pin-points their position. The hadron calorimeter measures the energy of pions, protons, etc, but because it is made out of laminated iron it also serves double duty as return yoke for the magnet.

UK contributions are very important to ALEPH. Glasgow, Lancaster, Sheffield, Westfield and Rutherford Appleton Laboratory (RAL) are collaborating in building the electromagnetic calorimeter elements for the end-caps; Imperial College is building the inner tracking chamber and its associated electronics for the trigger; Glasgow is working with Dortmund to provide a laser calibration system needed for the TPC; and RAL is responsible for some of the trigger electronics and a substantial part of the on-line data acquisition system. The end-cap calorimeter prototype, made jointly by RAL and Glasgow, will soon be shipped to CERN for testing. By mid-1984 the designs will be finalised incorporating all that has been learned from prototype and development work here and in France. If all goes well, the first of the 24 modules will be completed by mid-1985, and the last will appear early in 1988 in time for installation in the ALEPH experimental hall. Assembly of all the components of the detector will then take 18 months and the years of careful preparation will have produced one of the biggest pieces of physics apparatus ever built.

Ian Corbett, *RAL*



The ALEPH detector: a sectioned view

New antiproton collector ring

At its meeting in December 1983 the CERN Council approved the construction of a new antiproton collector ring (ACOL) that will greatly improve the quality of the antiproton beam and hence enhance experimental conditions in the proton-antiproton collider. This outstandingly successful facility has produced evidence of the W and Z particles, that 'carry' the weak nuclear force in the same way that electromagnetic forces are carried by photons (see *SERC Bulletin* Vol 2 Nos 8 and 9, Summer and Autumn 1983).

The basic limitation on the 'luminosity' of the collider facility is the accumulation rate of antiprotons. They are produced by CERN's proton synchrotron in bursts every 2.4 seconds and collected in an accumulator ring at a production rate at present of 10^{11} particles per day.

Placing the additional ring 'upstream' of the accumulator will increase the uniformity of the angular momenta of the antiprotons so that more of them will reach and be retained in the accumulator. The expected improvement is ten-fold.

ACOL consists of 24 dipole magnets and 56 quadrupoles in a 50-metre diameter ring, with radio-frequency accelerating systems and a pulsed lithium lens that will help to focus the beam of antiprotons. It should be in operation at the beginning of 1987 and will provide the prospect of some very important physics results. It will certainly allow more accurate measurement of the masses of the W and Z particles, in further confirmation of the electroweak unification theory. More exciting possibilities include the identification of further heavy particles predicted by force-unification theories but never yet supported by experimental evidence, and perhaps evidence for the existence of 'the missing quark', the elusive last of the six basic components of all nuclear matter.

Developments on Hawaii — at all levels

Mauna Kea Observatory, 4 km above sea level on the Big Island of Hawaii, is rapidly becoming one of the most active astronomical observatories in the world. SERC is making a major contribution to the development of the facilities there at the summit, at the mid-level facility and at sea level.

Mauna Kea is Hawaiian for 'white mountain'. It has that name because although it is within 20° of the equator it is often capped with snow during the winter season. The Sun is nearly overhead for a large part of the time but at 4200m the mean air temperature remains around freezing point throughout the year.

Summit

The altitude of the summit is superb for astronomical observations as it allows instruments to be sited above most of the interference from the atmosphere.

The dryness of the air above the site makes it particularly attractive for observations at infrared and submillimetre wavelengths. The UK Infrared Telescope (UKIRT) was opened in 1979 and now there are about a dozen ROE staff in Hawaii on three-year tours of duty.

The original UKIRT building at the summit was very basic and observers had to make the best of cramped conditions. An extension to the building has now been constructed and was officially opened on 4 November 1983 by the Astronomer Royal for Scotland, Professor Malcolm Longair. A control room for the UK/Netherlands Millimetre-wave Telescope will be located in this extension to the UKIRT building.

Mid-level

Because of the uncomfortable and potentially dangerous physiological effects of high altitude, observers do not sleep at the summit of Mauna Kea but in a dormitory facility at the 3000m level. The accommodation there was originally extremely primitive and discomfort had to be accepted as part of the price to be paid for the superb observing conditions on Mauna Kea. The accommodation was improved in the late 1970s and there has been a further very substantial improvement recently. The University of Hawaii, with financial support from SERC and the other users of the mountain, has constructed a comfortable building which was opened in August 1983.

Hawaii base

The ROE staff who run the UKIRT operation in Hawaii (and the locally recruited staff who work with them) all live in and around Hilo, the coastal town which is the administrative centre for the island. There is a lot of work to be done at sea level as well as at the summit and on any normal working day the majority of the staff are working in Hilo. In 1977, when the first members of the UKIRT team moved to Hawaii, a warehouse was rented in Hilo to serve as a base facility. An air-conditioned area (essential at sea level in the tropics) provides offices and laboratories, but these are now very overcrowded. Approval was given in March for construction of a substantial base facility which will eventually serve both the Infrared Telescope and the Millimetre Telescope. In addition to offices and laboratories for the resident staff there will be accommodation for visiting astronomers from the UK university community.

Home base

At present those who are awarded observing time on UKIRT have to travel to Hawaii where they are supported by a small team from the staff there. As reported in an earlier issue of *SERC Bulletin* (Vol 2 No 7, Spring 1983),

long-range, real-time communication experiments have been successful and work is now being done to make remote interaction between astronomers in the UK and the support staff at the telescope a routine matter. The base facility will be a key link in the complex communication line from the controlling astronomer to the telescope. The problems of developing remote observing are not trivial but when they have been overcome it will be possible for an astronomer to make night-time observations in Hawaii while sitting in front of a computer terminal in his or her own office in the UK.

Bennet McInnes
Royal Observatory, Edinburgh

Progress on the UK/NL Millimetre-wave Telescope

Construction of the UK/NL Millimetre-wave telescope facility is now well under way, particularly on the civil engineering side. The bases for the enclosure and the telescope are built and the fabrication of the steelwork for the rotating enclosure is complete.

The bases of the enclosure and telescope are together made up of some 1500 tonnes of reinforced concrete and already provide a significant new landmark at the Mauna Kea Observatory.

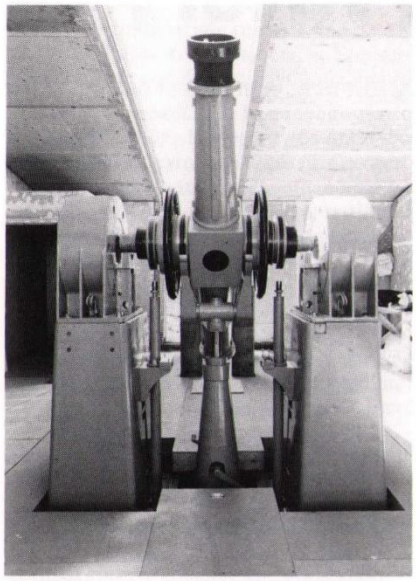
The steelwork for the carousel was prefabricated in the UK by Robert Watson & Co (Constructional Engineers) Ltd of Bolton and trial-erected for test purposes at their factory. On 24 November 1983 a special demonstration of the working carousel was attended by the Astronomer Royal, the Astronomer Royal for Scotland and the Director of the Rutherford Appleton Laboratory, as well as members of the project team from RAL; a team from the Royal Observatory, Edinburgh, who will administer the working telescope; several Dutch scientists; and representatives of the Hawaiian contractors who will erect the carousel on Mauna Kea. It was then dismantled and in February began its journey to Hawaii. Subject to the weather on Mauna Kea it is hoped to have a weathertight enclosure at the end of 1984.

Turning to the antenna, the structural design is now complete and tenders have been received for its manufacture. It is expected that trial erection at the manufacturer's premises will take place early in 1985, and that shipment to Hawaii will take place in Summer 1985 as planned. The design now includes a receiver cabin which will provide a controlled environment for the receivers.

The fabrication of surface panels was begun in 1983 and, as a result of further development during the year, panels are being produced to an accuracy higher than originally specified which will lead to improved performance of the facility.

The programme of research and development of receiver sub systems is being actively pursued in both the UK and the Netherlands and should lead to a well defined programme for construction later this year.

Observing begins on La Palma



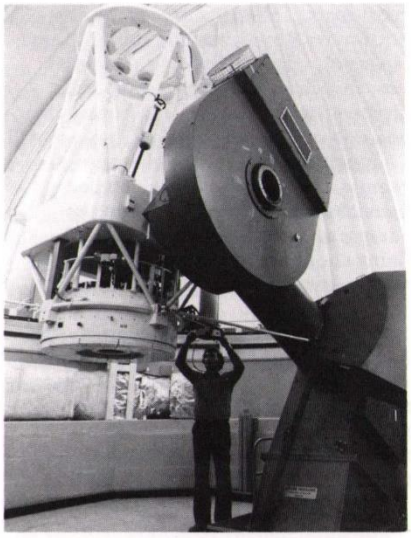
The Carlsberg Automatic Transit circle, a product of Anglo-Danish cooperation.

This year astronomers at the Royal Greenwich Observatory are beginning to see the fruits of many years' work as regular observing begins on the new telescopes at the Roque de Los Muchachos Observatory on La Palma – the Carlsberg Automatic Transit Circle (CATC), the Isaac Newton Telescope and the 1m Kapteyn Telescope.

The first of the telescopes to open its eye to the skies was the CATC which, in late November 1983, made some preliminary observations to align the telescope accurately. It began its first programme of systematic observations earlier this year.

A transit circle measures the position of stars as they cross the N-S meridian. The difference in the times at which they cross gives one component of their positions, corresponding to longitude on the Earth. The altitude at which they cross gives the other component, corresponding to latitude. The system of star positions so measured provides the basic reference grid to which the positions of all other objects, such as planets and galaxies, are referred. The positions of stars have to be measured over a period of years because uncertainties in their intrinsic motions gradually change the reference system defined by their positions.

The CATC is run jointly by an international team of astronomers from Copenhagen University Observatory, the Instituto y Observatorio de Marina, Spain, and the RGO. The operation of the telescope is completely automatic and as a result it has the potential to measure the positions of about half a million stars brighter than 12th magnitude. The CATC also makes daily observations of the positions of the Sun and planets.



The 1m Kapteyn Telescope installed in its dome at La Palma.

'First light' on the Isaac Newton Telescope occurred on the night of 13/14 February and both that telescope and the 1m telescope begin regular scheduled observing on 29 May. Astronomers are now delighted with the fine image quality created in the clear mountain air and will undoubtedly produce some exciting results in the coming months.

The largest telescope planned for the new Observatory is the 4.2 metre William Herschel Telescope. It is nearing completion at Grubb Parsons' factory in Newcastle where it is at present undergoing preliminary control tests. Later this year it will be dismantled and prepared for shipping to La Palma where the building is already under construction.

Spectators at Bolton for the trial erection of the Millimetre-wave Telescope carousel included (left to right): Mr Alan Watson (Managing Director, Robert Watson & Co), Dr Geoffrey Manning (Director, RAL), Dr Ron Newport (RAL Project Leader), Professor Graham Smith FRS (the Astronomer Royal) and Mr Roy Tolcher (Head of the Council Works Unit). The gigantic 400 tonne structure, which is supported on 14 bogies, towers 25 m high and has a 28 m diameter.

The archives of the Royal Greenwich Observatory

The Royal Greenwich Observatory (RGO) is by far the oldest scientific establishment in Britain to be funded by central government. It was founded by Charles II in 1675 at Greenwich Park in London and is now situated at Herstmonceux in East Sussex. In recognition of their great importance as a single collection of papers both scientific and administrative, RGO Archives have been granted exemption from that section of the Public Records Act which instructs all government bodies to deposit their records at the Public Record Office, Kew. RGO is thus responsible, by law, for the maintenance of its own collections at Herstmonceux.

The Archives predate the foundation of the Observatory. John Flamsteed, the first Astronomer Royal, was the son of Steven Flamsteed, who managed a substantial Derbyshire lead mining concern. John inherited Steven's papers and bound them up in one of his letter books. They are still of importance to historians because, for example, they contain quite detailed financial statements and indicate the widespread use of gunpowder in lead mining about twenty years before any other known source.

Flamsteed's papers as a whole are most important scientifically because they are one of the earliest and one of the most complete collections for any British astronomer. Records of his years of meticulous observations with sextant and mural arc are all here: the raw material of his great posthumous *Historiae Coelestus Britannicae.* They are still consulted by astronomers looking for early records to compare with present day observations and for pre-discovery records of, for example, Uranus. Flamsteed did actually see Uranus but he thought it was a 'periodic' star. Also, Flamsteed corresponded widely with other men of science both at home and abroad – men like Cassini, David Gregory, Hevelius, Halley, Abraham Sharp, Newton, Pound, Plume and Whiston. This sets the pattern for his successors as Astronomer Royal. They were all men of science in the widest sense and their correspondence is important in the history of science as a whole.

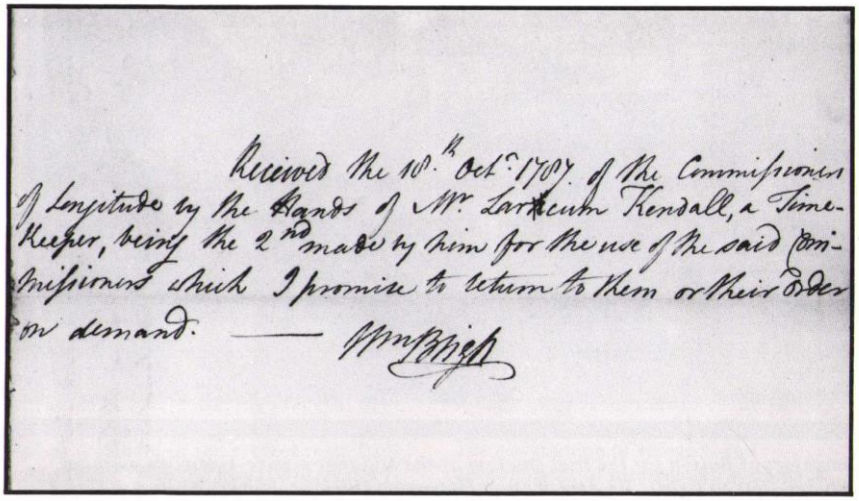
Nevil Maskelyne, the fourth Astronomer Royal (from 1765 to 1811) is so closely associated with the Board of Longitude that is is sometimes difficult to tell which papers belong in which collection. Maskelyne was quite keen to win the Longitude prize eventually awarded to John Harrison. The whole history of man's attempts to find longitude at sea – methods both reasonable and scientifically possible or, as the Board itself labelled them, 'Impractical and Irrational Schemes' – are in these papers, as is the history of most of the early British chronometer-makers such as Harrison himself, Mudge, Earnshaw, Kendall and Pennington. The Board of Longitude sponsored many early voyages of exploration, so RGO Archives have the manuscript logs of Captain Cook's second and third voyages in *Adventure* and *Resolution* as well as the astronomical observations made on those and other voyages. Maskelyne himself published the first edition of the *Nautical Almanac* in 1767. He also attempted to 'weigh the earth' by calculating the mass of the mountain Schiehallion in Perthshire. This experiment was one of the really important scientific firsts: the first true test of Newton's law of gravity, the first determination of the universal constant of gravitation (the big G) and the first occasion upon which contour lines were used in mapping (by Reuben Barrow of the Observatory and Charles Hutton of the Royal Society, Maskelyne's assistants in the experiment).

George Biddell Airy, the great Victorian Astronomer Royal (1835-1881), was responsible for by far the largest collection of papers in the Observatory Archives, one of the largest surviving collections of any British scientist. He kept the records of his Observatory, both administrative and scientific, with meticulous care, making himself personally responsible for their filing and instituting a system of reproducing out-going letters so that, for the first time, both sides of the correspondence of the Observatory were systematically preserved. At that time, Airy was still the only Government scientist and sat on almost as many boards and committees as scientists do today. He was consulted about the clock for the new Palace of Westminister (Big Ben), the correction of compasses in iron ships, the measurement of tides (particularly in Ireland), the Great Exhibition of 1851, the Paris Exhibition of 1855 and the gold standard (by the Bank of England), among many other projects.

This was all in addition to the regular scientific work of the Observatory which was carried out at a level of excellence unmatched anywhere. Indeed, in 1884, three years after Airy retired, an international conference in Washington agreed that the zero of longitude, on which all navigational charts would henceforth be based, should run through the transit instrument at Greenwich Park, which is now the prime meridian of the world.

Archives are the raw material of history. They are there to be interpreted and reinterpreted by this and by subsequent generations. In the scientific field the archives of the RGO are unique, irreplaceable and of primary importance in our understanding of the history and development of science both in this country and abroad.

J Dudley
Librarian and Archivist,
Royal Greenwich Observatory.


Received the 10th Oct: 1787 of the Commissioners of Longitude by the Hands of Mr Larkum Kendall, a Time-Keeper, being the 2d made by him for the use of the said Commissioners which I promise to return to them or their Order on demand. —— Wm Bligh

Captain William Bligh's receipt for the chronometer by Kendall from the Commissioners of Longitude, issued to **HMS Bounty** *in 1787. (RGO 14/13)*

Quasar research at RGO

Part 3: The double quasar

This is the third article (parts 1 and 2: SERC Bulletins Vol 2 Nos 9 and 10) describing research at the Royal Greenwich Observatory on QSOs (quasi-stellar objects, or 'quasars'), faint blue star-like objects generally believed to be the super-active nuclei of very distant galaxies. This concluding part concerns two research programmes involving the astonishing system 0957+56A,B — the 'double quasar'.

General Relativity predicts that the gravitational field of a body of mass M 'warps' the space in its vicinity to form a gravitational lens which deflects electromagnetic radiation passing at a distance d inward by an angle proportional to M/d. The famous eclipse expeditions of 1919 indeed detected the predicted shift of 1.75 arcsec in the position of star images at the edge of the solar disk. Because the radiation bending is inversely proportional to d, there is no focal point; a gravitational lens does not form a real image, but it does form a virtual image, magnified and intensified.

'Lensing' a QSO image?

In theory, then, massive foreground objects can gravitationally 'lens' the image of background objects. Quasars are the most distant objects which astronomers observe; they are seen through a veil of foreground galaxies. So could a galaxy lens a QSO image? The possibility remained science fiction for most astronomers until Dr Dennis Walsh of Jodrell Bank (with colleagues Dr R F Carswell of the Institute of Astronomy, Cambridge, and Dr R J Weymann of University of Arizona) suggested that the twin images near the position of the radio source 0957+56 represented a lensed quasar. These images appear on optical plates (figure 1) as stellar and separated by 6 arcsec; the optical spectra show the same emission and absorption lines, with identical emission-line redshifts (see part 2) of 1.41. Subsequent observations, at UV, optical, and radio wavelengths, confirm that the system is truly the result of gravitational lensing. In fact the lensing galaxy between the two images has now been detected, its redshift ($z = 0.37$) measured, and its mass distribution modelled.

At RGO the 26-in refractor has been used to follow the brightness variations of the twin images for the past several years. Results are shown in figure 2. In conjunction with observations from archival plates (images of the system are present on plates taken as long ago as 1902), the recent observations show that variations in light output by a factor of 2.5 take place over periods of tens of years; but the difference between the two images at any time rarely exceeds 30%. Figure 2 shows that B underwent an outburst of about 40% peaking in June 1980, while A has remained relatively constant. Detailed models of the mass distribution forming the gravitational lens suggest that the light path for image A is somewhat smaller than that for image B.

Four-year difference

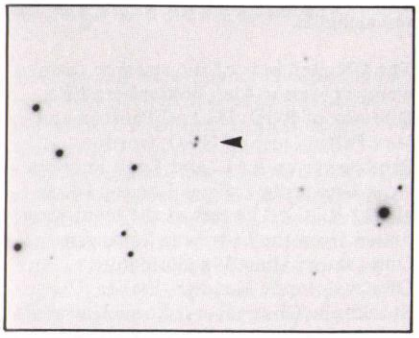
In fact the delays between light variations in the two images enable us to estimate that the light paths differ by at least four years. We can surmise that the June 1980 peak of B was reached before 1976 by A; and we can suggest that B will settle down to three years of constant luminosity shown by A between 1979 and 1982. A further point of interest is that the light curves of most (non-lensed) QSOs with radio-emission similar to that of 0957+56 show light-variations over periods of years with amplitudes similar in magnitude to that shown by the components of 0957+56, with occasional abrupt changes of slope and periods of constancy. This is exactly as seen for components 0957+56A and B during the last few years; it strongly suggests that the variations are intrinsic to the quasar, and have nothing to do with the lensing galaxy or, in particular, with the motions of individual stars in the galaxy, as some authors have suggested.

A second investigation in which RGO scientists have played a leading role concerns detailed spectroscopy of the two images. Part 2 discussed the origin of heavy-element absorption lines in QSO spectra, and described how observations favoured the hypothesis that they are produced in intervening galaxies along the lines-of-sight. In the case of the double quasar, two absorption-line systems are known in the spectra of each image, at identical redshifts of $z = 1.12$ and 1.39. It is important for the intervening hypothesis that the precise structure of the absorption lines be different in A and B, as their lines-of-sight must pass through widely separated parts of the galaxy producing the absorption lines. (The lensing galaxy itself contains too little gas to produce prominent absorption lines at its redshift of 0.37). A recent collaborative investigation with astronomers from the California Institute of Technology used an Image Photon Counting System (see part 2) on the spectrograph of the 5 m telescope of the Hale Observatories to search for such differences. Data of exceptionally high resolution and quality were obtained, which show structural differences in the CIV doublet lines, and the intervening galaxy hypothesis therefore remains strongly favoured.

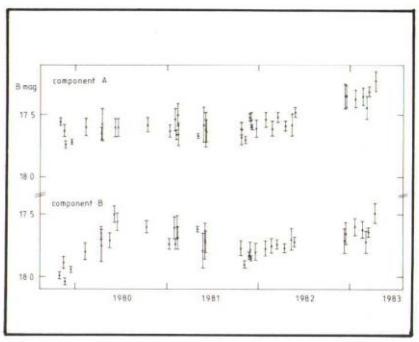
Undiminished impact

A few more lens systems are now known, and the acceptance of the phenomenon as part of the astrophysical fabric is now general. After 21 years of quasars, their impact on atomic physics, astrophysics, General Relativity and cosmology remains undiminished.

Dr J V Wall
Head of Astrophysics and Astrometry, RGO



Left:
Figure 1. The double quasar 0957+56A,B as observed with the 26-in RGO refractor at Herstmonceux.



Right:
Figure 2. Recent light curves of 0957+56A and B as measured from plates taken with the 26 inch refractor. Magnitude is -2.5 x log (intensity).

Black hole in a mini-quasar 'weighed' by IUE

Data gathered by the International Ultraviolet Explorer (IUE) satellite have enabled astronomers to 'weigh' a gigantic black hole.

After studying ultraviolet light from a nearby galaxy by means of the IUE, an international research team, with leading members from the Royal Greenwich Observatory and Rutherford Appleton Laboratory, has reached the conclusion that the quasar-like heart of the galaxy known as NGC 4151 is powered by a black hole some 500 million times heavier than the Sun.

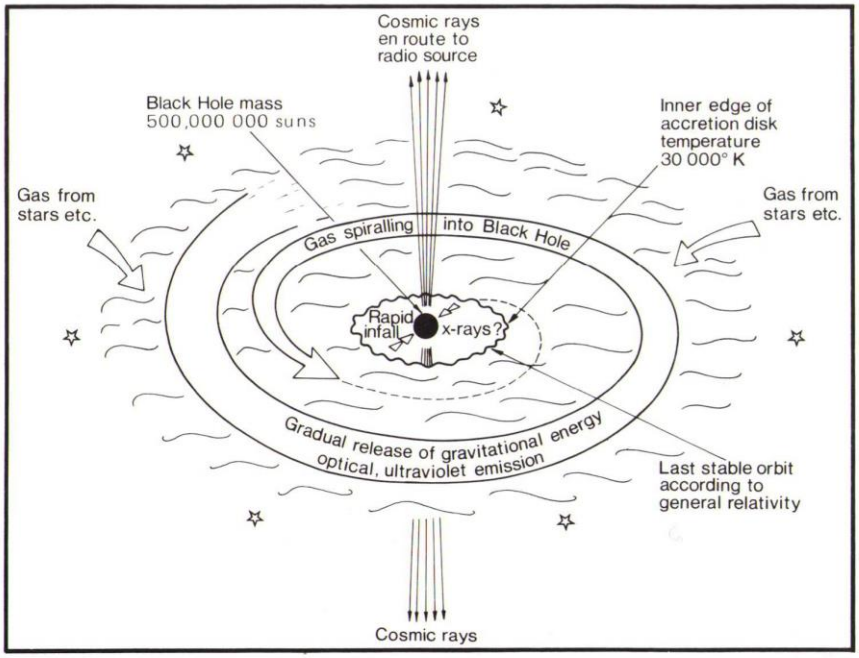
Although UK and American astronomers working at the Kitt Peak National Observatory in Arizona proposed the existence of a massive black hole in another galaxy – M87 – a few years ago, this is the first time that astronomers have actually weighed one, and the discovery strengthens the theory that the immense and concentrated power of a quasar is due to gas swirling around a very massive black hole in the centre of a galaxy.

The team has been studying NGC 4151 since 1978. To weigh its centre, they investigated gas clouds very close to the galaxy's core. The team found that the clouds are moving at speeds up to 14,000 km/second and ascertained the distances of the clouds from the core, by finding the time it took for a brightening of the core to 'light up' the clouds.

The observations show that the slower-moving gas clouds lie farther from the core. This fits with the idea that the clouds orbit around a very massive object at the centre of the galaxy NGC 4151 (as the planets orbit the Sun at the centre of the Solar System). The speeds and distances of the gas clouds show that this object is 500 million times heavier than the Sun – and the only kind of object which can be so massive, yet small enough, is a black hole.

In 1969 Professor Donald Lynden-Bell, then at RGO and now of the Institute of Astronomy, Cambridge, proposed that quasars are caused by black holes at the centres of galaxies. Gas from the galaxy spirals inwards, under the influence of the black hole's gravity, and in the process becomes hot and emits radiation. The most powerful quasars would have a black hole 500 million times heavier than the Sun. Such quasars are rare but many otherwise normal galaxies could have a mini-quasar at the centre, powered by a black hole of around 50 to 100 million Suns.

NGC 4151 fits this description very well. It is the nearest bright Seyfert galaxy, lying some 50 million light years away in the direction of the constellation Canes Venatici, and has a central 'mini-quasar' core: a very small, very bright region where gas clouds move at high speeds.



The researchers, from the UK, France, Italy, Sweden and Germany, investigated the galaxy's core with the 45 cm telescope on board the IUE, which is a joint project of SERC, NASA and the European Space Agency. The satellite and its ultraviolet-sensitive television cameras, supported by a team at RAL, have performed excellently since launch in 1978, providing astronomers with a wealth of information about many celestial objects.

Most of the ultraviolet radiation from the galaxy's core region arises in an extremely compact central 'powerhouse'; but there are also spectral lines (at particular wavelengths) which come from gas clouds outside the core. The team identified three different types of gas cloud emitting characteristic spectral lines. For each type of cloud, knowing the speed of the cloud and its distance from the core permits calculation of the centrifugal force. This force must be balanced by the gravitational attraction of the core and an application of Newton's law of gravity to the speed and distances from the central object gives the mass of the latter. All three give very similar answers for the core: about 500 million Suns.

The observations also support the black hole theory in another, completely independent, way. As the gas spirals into the black hole, it should form into a swirling 'accretion' disc. The disc should be at a temperature of 30,000K, and stretch to about ten times the size of the black hole itself. Inside the accretion disc, where gas falls into the black hole, lies the energetic powerhouse, producing most of the core's energy. But the hot gas in the disc should produce characteristic ultraviolet radiation of its own – and the new observations do indeed reveal radiation of the correct intensity over the predicted range of wavelengths.

The UK members of the research team were: Professor Alec Boksenberg FRS, Director of RGO; Michael Penston and Max Pettini, also of RGO; Gordon Bromage from RAL; and Toon Snijders from University College London (now also at RGO). The rest of the team were drawn from the European Southern Observatory (based in Germany); Observatoire de Meudon, France; Stockholm Observatory; Rome University; and the Instituto di Fisica Cosmica in Milan.

AMPTE space mission on schedule

The Active Magnetospheric Particle Tracer Explorers (AMPTE) – three spacecraft, from West Germany, the UK and USA, combined in one mission – are on schedule for launch in August 1984. They will be launched by a single Thor Delta rocket to trace the flow of solar wind ions into the Earth's magnetosphere using injected ions; to investigate plasma phenomena induced by the tracer ions; and to study the natural particles, fields and waves of the magnetosphere. The mission is expected to last about one year (see *SERC Bulletin* Vol 2 No 10, Spring 1984).

The mission will use the solar wind and magnetosphere as a plasma physics laboratory. The UK spacecraft (UKS), working in tandem with the German craft, will have a particular role in resolving what would otherwise be an ambiguity between variations with time and structure encountered along the orbit. The first ion releases will be of Lithium and will take place some 16-18 RE upstream. Another release will take place along the flanks of the magnetosphere where a short-lived 'comet', visible from the ground, will be produced. There will also be releases in the plasma deep within the tail of the magnetosphere, with the possible production of an artificial aurora.

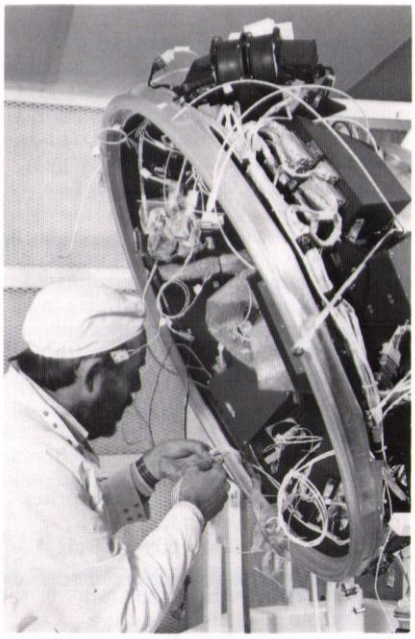
The UK spacecraft

UKS was jointly built at Rutherford Appleton Laboratory (RAL) and the Mullard Space Science Laboratory (MSSL) of University College London. It is constructed in place of the conical adaptor originally linking the German and US satellites in the launch configuration. Attached to the cone are 12 panels supporting the solar array. Detectors and other instruments and systems are mounted on the cone itself (see picture). The UKS is about 1m in diameter and weighs 74kg. It has two pairs of deployable booms, one pair carrying the magnetometer and wave-experiment search coil and one pair the electric field experiment pre-amplifiers, the latter measuring about 7m tip-to-tip.

The spacecraft will be spin-stabilised with its spin axis normal to the ecliptic plane. Attitude control will be effected by pressurised nitrogen thrusters guided by data provided by Sun and Earth sensors. A magnetorquer coil may be used occasionally. The gas thrusters will also be used for station-keeping with the German satellite to maintain a separation of approximately 100km. This task will make use of an on-board radar developed specially for the purpose.

Extensive test

After tests at RAL, MSSL, British Aerospace (Filton and Stevenage) and RAE (Farnborough) last Autumn, the satellite was shipped to Munich for vibration tests with the other two AMPTE spacecraft. Further tests followed: at RAL, boom deployment and pyrotechnic tests; at British Aerospace, further electromagnetic interference checks and mass properties and spin balance tests; magnetic calibration at RAE and Hartland Magnetic Observatory, Devon; sensor alignment and calibration at MSSL and solar simulation and vibration tests in Germany.



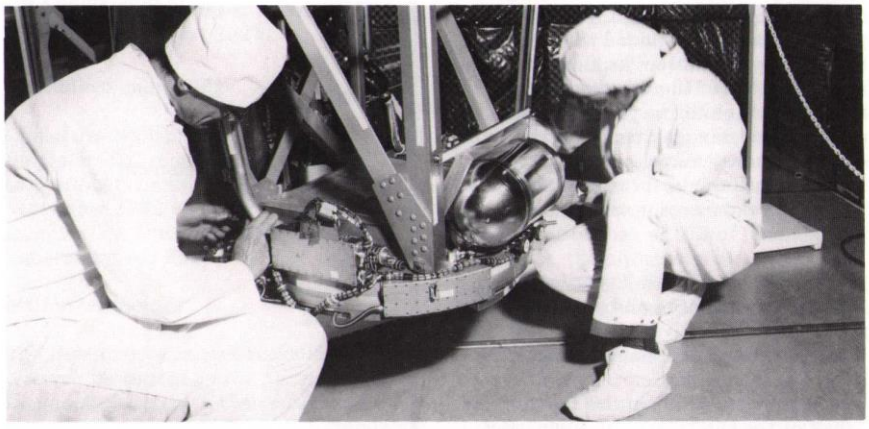
The UK spacecraft for the AMPTE mission under construction at RAL

Final operational tests at the UK Control Centre at RAL are scheduled for May, and the spacecraft is then due to be shipped to the Kennedy Space Center, to be prepared for launch on 9 August.

The UKS will be controlled from RAL's ground station at Chilton, using the 12m dish previously used for IRAS. Data will be received using the 26m dish at Chilbolton in Hampshire.

Spacelab 2 experiment

The two UK experiments for Spacelab 2 have now been delivered to NASA for integration. Seen here is Birmingham University's Coded Mask Telescope undergoing predelivery qualification tests at Marconi Space and Defence Systems, Portsmouth, in February. The instrument was then shipped to the Goddard Space Flight Centre, about the same time as CHASE, the joint project between the Mullard Space Science Laboratory, University College London and the Space and Astrophysics Division at RAL.



Projects or programmes?

A new road for university research in marine technology

The current two-year programme of research in marine technology which started in July 1983 comprises 250 separate projects and is supported by SERC at a total level of around £8 million at seven university marine technology centres and 20 individual academic institutions.

The Marine Technology Directorate's primary aim is to develop a coordinated programme of research and training in marine technology in universities and polytechnics which will attract industrial support. To further this aim, more than half of the new funding is provided to support eleven cohesive programmes as listed in the tables. Each of these programmes has been developed with industry and government and comprises a number of interdependent or interlinked, complementary projects directed towards a common overall aim or set of aims. Contributions from industry and government to these programmes seem likely to be of the order of £1½ million over the two-year period as compared with £4 million from SERC. Present indications are that the total contributions from these sources to university work, including that in areas related to the SERC programme but not necessarily directly associated with it, will increase towards the target for 1987 of £3 million per annum.

Technical device

Six of these cohesive programmes have been formulated specifically to meet perceived industrial needs (Table 1) and the remainder have been formulated on a more traditional discipline basis (Table 2). The steering committees associated with most of them are essentially technical advisory committees of the Management Committee. For the programmes jointly funded with industry, the steering committees include representatives of the subscribers. In addition to monitoring progress on approved programmes, some steering committees may also advise the Management Committee on desirable further developments in related technical areas.

The executive responsibility for a Committee's activities and programme development initiatives normally rest with a Programme Champion, who is a leading academic participating in the programme and acting in this role on behalf of the Directorate. In some cases, and particularly where the programme is jointly sponsored with industry and government, the Programme Champion may be assisted by a Programme Manager under contract from a commercial company. The relationship between a Programme Champion and Programme Manager is subject to agreement by both parties and the steering committee but, in general terms, the Programme Manager is responsible for setting down a succinct account of the approved programme, monitoring its execution and disseminating results while the Programme Champion will act as spokesman for the academic participants and takes a rather broader, longer-term view of the programme and its desirable further development. Members of steering committees are nominated by Programme Champions and endorsed by the Marine Technology Directorate and its Management Committee who ensure that commitments to any cosponsors in respect of representation are honoured.

Further information on any of the programmes or the differing methods of project management employed may be obtained from

The Marine Technology Directorate,
SERC, 3-5 Charing Cross Road,
LONDON WC2H 0HW,
telephone 01-930 9162.

Table 1
Cohesive programmes developed in consideration of industrial needs

Title	Programme Champion
Marginal offshore fields	Professor A R Halliwell (Heriot-Watt)
Coastal engineering	Professor D M McDowell (Manchester)
Dynamic response of cylinders (Christchurch Bay tower experiment)	Mr G Tickell (Liverpool)
Structural integrity monitoring	Dr J Billingham (Cranfield)
Dynamic response of compliant systems	Dr W R Eatock-Taylor (University College London)
Wire rope	Dr R Chaplin (Reading)

Table 2
Cohesive programmes with a traditional discipline base

Title	Programme Champion
Fluid loading	Dr P W Bearman (Imperial College, London)
Defect tolerance assessment	Dr M J Cowling (Glasgow)
Fatigue	Professor W D Dover (University College London)
Buckling	Professor A C Walker (Surrey)
Grouting	Professor P L Pratt (Imperial College, London)

Biotechnology: support for microbial physiology

The Summer 1983 issue of *SERC Bulletin* (Vol 2 No 8) contained a description of SERC's strategy for the support of biotechnology which included, as a key element, the selective support of a number of priority sectors. This policy is now being actively implemented and one of the priority areas, microbial physiology, has recently received substantial funding from the Biotechnology Directorate.

UK activity in the field of microbial physiology has declined over the last decade as microbiologists have directed their attention to the growing field of microbial genetics. The development of recombinant DNA techniques has proved central to biotechnology, but has been based on one or two bacterial species, most notably *E.coli.* Before these techniques can be effectively applied to less well-characterised organisms, more information is required on their basic physiology. Furthermore, it is now becoming clear that the successful development of novel fermentation techniques requires more knowledge of the physiological responses of microorganisms to changes in their environment.

In order to develop the research base in microbial physiology the Biotechnology Directorate entered into discussions with a number of leading groups in the area and in November 1983 support totalling almost £400,000 was given to two programmes at Aberystwyth and Warwick.

The award to Professor J G Morris at the University College of Wales, Aberystwyth, is to support physiological and genetic studies of biotransformations by anaerobic bacteria. The work will concentrate on the influence of different culture conditions such as immobilisation of the cells and 'non-steady state' continuous culture on the ability to carry out specific reductions.

Professor H Dalton at Warwick University received support to study oxygenase-based bioconversions of organic molecules. The chemical industry is showing increasing interest in the use of biological catalysts as many of them can effect single step highly selective conversions that often require several steps by traditional chemical routes. The work will investigate the cause of oxygenase instability in several bioconversion systems which should lead to improvements in commercially exploited processes.

Some new publications from SERC

All publications described are available from the appropriate section of the Council, free, except where otherwise stated.

Biotechnology in British industry

A major report entitled *Biotechnology and British industry* has been prepared for SERC's Biotechnology Directorate by Dr Peter Dunnill and Dr Martin Rudd of the Department of Chemical and Biochemical Engineering of University College London.

The report, which discusses the potential applications of biotechnology across the entire range of British industry, is available for purchase. Enquiries to the Biotechnology Directorate at SERC Central Office, Swindon, ext 2310.

Biological sciences

Copies of the *Biological Sciences Committee annual report 1982-83* are available from the Committee Secretariat, SERC Central Office, Swindon, ext 2156.

Engineering processes

Engineering Processes Committee annual report 1982-83 is available from the Committee Secretariat at SERC Central Office, Swindon, ext 2250.

Energy

Copies of the *Energy Committee annual report 1982-83* are available from the Energy Research Support Unit at Rutherford Appleton Laboratory, ext 5440.

Joint ESRC/SERC Committee

Two reports are now available:

Interdisciplinary research: selection supervision and training: and *Phd thesis titles 1973 to 1982.*

Both reports are available from the Committee Secretariat at SERC Central Office, Swindon, ext 2429.

Distributed computing

Copies are available of *The coordinated programme of research in distributed computing systems: annual report September 1982 - September 1983* from Dr D A Duce, Rutherford Appleton Laboratory, ext 5511.

Marine technology

The *Directory of marine technology research sponsored by the Science and Engineering Research Council* is available from the Marine Technology Directorate's office in London, telephone 01-930 9162.

Royal Observatory, Edinburgh

An illustrated report has been produced by the Royal Observatory, Edinburgh, entitled *Research and Facilities 1983.* It highlights the Observatory's research projects and describes its major facilities: the UK Schmidt Telescope, Image and Data Processing, the UK Infrared Telescope and the UK/Netherlands Millimetre-wave Telescope.

Copies may be obtained from the Observatory, telephone 031-667 3321.

ESF handbook on thermoluminescence dating

The European Science Foundation has produced a 50 page handbook on Thermoluminescence (TL) dating. Primarily aimed at archaeologists and archaeological scientists, the booklet is the first in a proposed series on scientific methods in archaeology, prepared by the ESF Subcommittee for Archaeology. This Subcommittee has, as one of its main objectives, the promotion of interdisciplinary contact between archaeologists and scientists.

Copies of the booklet are available from:

The Council for British Archaeology, 112 Kennington Road, London SE11 6RE; telephone 01-582 0494.

Studentship numbers 1983/84

1983 report

The Council allocated 3337 studentships for 1983, of which 801 were directed specifically to the CASE scheme. This represented an overall increase of 177 on the allocation for 1982.

Competition at the subsequent appeals stage remained keen with over 900 applicants contending for 70 awards. Forty seven candidates with first class honours failed to obtain an award.

The year was marked by the decision of the Department of Education and Science, following the recommendation of the Alvey Committee, to release funds for the support of training in Information Technology. In this first year of the initiative 120 research studentships and 94 advanced course studentships were provided. In addition, 906 conversion course studentships were allocated. These are similar to advanced course studentships but are directed towards graduates or their equivalent with a background not necessarily scientific. Of the total of 1120 IT studentships provided, 1096 had been taken up by October 1983.

Table 1 compares the distribution of studentships taken up by October 1983 with the original target.

Table 1: Distribution of 1983 awards taken up at October 1983

(1983 provision agreed by Council in brackets)

	ASR	Engineering	NP	Science	Polytechnics	ESRC/SERC	Biotech-nology	Total	Information Technology
Research studentships									
Standard	65 (65)	361 (373)	53(53)	793 (757)	21(21)	39 (35)	30(30)	1362(1334)	152 (93)
CASE/CTA	9 (8)	445 (327)	7 (6)	437 (453)		2 (2)	25(25)	925 (821)	22 (27)
Instant	3 (3)	22 (20)	2 (2)	66 (70)		1 (-)		94 (95)	
Total RS	77 (76)	828 (720)	62(61)	1296(1280)	21(21)	42 (37)	55(55)	2381(2250)	174 (120)
Advanced course studentships									
Standard	26 (27)	353 (490)		312 (304)	10(10)	57 (56)	31(35)	789 (922)	144 (94)
Instant	1 (1)	102 (110)		19 (21)		13 (13)	3 (-)	138 (145)	
Conversion									778 (906)
Total ACS	27 (28)	455 (600)		331 (325)	10(10)	70 (69)	34(35)	927(1067)	922(1000)
Awards tenable overseas	3 (-)	3 (-)		6 (-)		4 (-)		16 (20)	
Total	107(104)	1286(1320)	62(61)	1633(1605)	31(31)	116(106)	89(90)	3324(3337)	1096(1120)

Note Council's targets for awards tenable overseas were not broken down between Boards.

Table 2: Allocations decided by Boards etc for 1984

	ASR	Engineering	NP	Science	Polytechnics	ESRC/SERC	Biotechnology	Information Technology	Total
Research studentships									
Standard	67	435	55	800	21	38	32	152	1600
CASE	8	395	7	453		5	25		893
Instant	3	20	2	70					95
Advanced course studentships									
Standard	21	440		304	10	56	30	134	995
Instant	1	110		21		13			145
Conversion courses (IT only)								1068	1068
Awards tenable overseas									20
Total	100	1400	64	1648	31	112	87	1354	4816

Plans for 1984

A target is set for 1984 of 3462 mainstream awards and 1354 awards allocated specifically to Information Technology, ie, increases from 1983 of 125 and 234 awards respectively.

There are two significant changes; first in the provision by the Engineering Board, where a net increase of 80 results from an increase of 130 research studentships and a decrease of 50 advanced course studentships; and secondly in the increase of 43 Science Board research studentships, these to be earmarked for identified research grants. In the field of Information Technology the emphasis continues to be on conversion courses. While the number of courses will remain virtually unchanged for 1984, the number of awards is being increased to meet the expected increase in demand from students.

The CTA scheme is now assimilated with the CASE scheme. It should be noted that from 1985 there will be a single closing date for CASE project applications of 31 January.

Table 2 sets out the distribution of studentships to be made in 1984, and includes those awards for Information Technology made available under the Alvey programme.

Research grants

SERC support for major equipment

SERC wishes to clarify its policy on the contributions expected from institutions towards major equipment or expensive instruments (costing more than £100,000) sought under SERC research grants.

In future, applications involving requests for expensive equipment (apart from computers, for which there are separate arrangements) will be considered in relation to its expected use on two fronts: use on the project for which SERC support is being sought, and use for other work by the department. If the use for other work is expected to be marginal, SERC will not require a contribution from the institution. But if more than 20% of the available time is expected to be taken up by the other work, SERC will ask the institution to make a contribution in proportion.

Details of this policy were announced to academic institutions in letter RG 5/84 on 31 January 1984.

PhD submission rates

Studentship awards beginning in 1979

Although the Council has always seen its awards as made to provide a training in research and not necessarily for the attainment of a degree, it remains strongly of the view that the writing up of results within a reasonable timescale is an integral and important part of research training. Thesis submission provides an effective measure of whether this part of the student's training has been satisfactorily accomplished. In line with this view the Council publishes each year the submission rates at each institution.

The tables which follow set out the results of the fourth annual survey of PhD submission rates for SERC research students. This survey relates to those students whose awards began in 1979.

Institutions were asked to give details of (i) those students who had formally submitted a thesis by October 1983 and (ii) those students who remained registered for a PhD on that date.

The information is set out by institution in Table 1 and by SERC subject area in Table 2.

Table 1: PhD submission rates etc by institution

Institutions	Number of students registered	Number submitting by 1.10.83	Number still registered at 1.10.83
Aston	63	32	16
Bath	30	13	16
Birmingham	79	48	23
Bradford	43	15	20
Bristol	65	31	29
Brunel	13	4	6
Cambridge	159	105	39
City	15	6	8
Cranfield Institute of Technology	11	4	3
Durham	40	22	14
East Anglia	35	21	12
Essex	11	1	8
Exeter	18	9	7
Hull	16	9	3
Keele	8	2	6
Kent	26	5	12
Lancaster	15	13	2
Leeds	87	38	41
Leicester	37	25	6
Liverpool	55	29	19
London:			
Bedford	10	3	7
Birkbeck	11	7	4
Chelsea	13	4	9
Imperial	129	67	52
Kings	22	13	7
Queen Elizabeth	14	5	7
Queen Mary	31	18	11
Royal Holloway	12	4	8
University	60	19	28
Westfield	7	2	3
Other institutions	26	16	6
Loughborough	23	9	12
Manchester	101	50	38
UMIST	54	24	23
Newcastle	45	26	19
Nottingham	70	34	26
Open	12	5	7
Oxford	130	79	35
Reading	39	20	16
Salford	32	13	17
Sheffield	68	29	36
Southampton	53	23	25
Surrey	30	21	9
Sussex	37	15	11
Warwick	37	12	19
York	26	10	12
University of Wales:			
Aberystwyth	24	11	13
Bangor	21	11	9
Cardiff	25	8	10
Swansea	31	9	19
UWIST	15	3	10
Aberdeen	21	10	8
Dundee	8	5	2
Edinburgh	51	22	20
Glasgow	41	19	18
Heriot-Watt	26	12	9
St Andrews	17	12	4
Stirling	12	3	6
Strathclyde	39	20	14
Ulster	1	0	1
Queens Belfast	3	2	1
Total universities	2253	1107	881
Total polytechnics*	98	24	55
Other institutions*	24	5	11
Grand total	2375	1136	947

* The numbers of students at polytechnics and other institutions were generally too low to make individual detail useful.

Table 2: PhD submission rates etc by SERC Board

Science Board	1424	751	522
Biological Sciences	567	256	250
Chemistry	525	338	150
Mathematics	157	72	49
Physics, Neutron Beam and SBA*	175	85	73
Engineering Board (including Eng/Maths)	716	279	332
ASR Board	80	40	34
NP Board	58	41	12
ESRC/SERC Committee	64	17	28
†Other	33	8	19
Grand total	2375	1136	947

* SBA = Science-based Archaeology
† Other = Energy Commitee and Polytechnics Committee

Infrared astronomy at the AAT

The sleek white dome of the Anglo-Australian Telescope (AAT), on the wooded slopes of Siding Spring Mountain in New South Wales, contains not only one of the most prestigious of modern telescopes but also a battery of sophisticated astronomical instruments to mount on it. Of these, the Infrared Photometer/Spectrometer (IRPS) was the first to be built wholly by the staff of the Anglo-Australian Observatory. When commissioned on the telescope in 1978, the IRPS was the first common-user infrared instrument available to British and Australian astronomers and it immediately attracted considerable use. Over the past five years it has accounted for 20% of observing time on the telescope.

On the outside, the IRPS appears entirely conventional. The heart of the instrument lies within a Dewar whose function is to provide a chilled environment – 50 K – for the indium antimonide (InSb) detector. Attached to the Dewar is rather more electronic equipment than is the norm, through which both the control and the data can be handled from the telescope control room.

The IRPS is distinguished from other infrared systems by its inner electronics. When infrared radiation falls upon a detector, electrons flow from it and, in more conventional systems, these electrons are forced through a 'feedback' resistor to generate a measurable voltage. A modern high-performance InSb detector has a resistance in excess of 10^{12} ohms and necessitates a feedback resistor of comparable value. Many undesirable features are then introduced. For example, noise is injected by the feedback resistor, which also introduces long-time constants and leads to saturation at quite low photon rates.

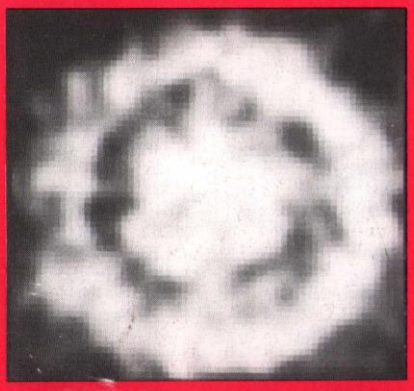
In the AAT electronics, the resistor is replaced by a capacitor on which charge accumulates. The capacitor is periodically sampled and discharged. With this style of signal processing we have achieved lower noise than any other infrared system, can sample at arbitrarily high rates and can observe every celestial object except the Sun without saturation. Moreover, the system is extraordinarily versatile. The orginal facility was designed either to measure the brightness of objects through any of several filters (the photometric mode) or to secure spectroscopic observations. Exactly the same configuration has now also been used for speckle observations, enabling detail finer than the atmospheric turbulence to be extracted. With a polarizing filter mounted in front of the Dewar, polarization measurements have been possible of sources fainter than ever previously studied. A recent development has been the introduction of the imaging mode, in 1983.

Two-dimensional infrared detectors suitable for astronomical use are still some way off. All infrared pictures have to be made by sampling the sky point by point. In conventional infrared systems it has also been necessary to difference the signal from that in a neighbouring patch of blank sky, in order to correct for the sky and telescope emission. This procedure causes problems when scanning a raster pattern to build up a picture. First, if the object under study is extended, or the field crowded with stars, then the supposedly blank sky may actually not be blank at all, so that a badly distorted image can result. Second, the observer spends half of his time observing sky, when strictly this is not necessary.

In the AAT's imaging infrared facility, the high precision of the telescope control enables very accurate scanning to be undertaken. There is no confusion due to differencing neighbouring patches of sky, and the results are presented on-line to the observer. The imaging facility has proved very popular: it is teaching us what the infrared sky really looks like and is setting the scene for the day – it is hoped not too many years distant – when complete two-dimensional detectors will make it redundant.

By combining images at different wavelengths it has been possible to generate infrared colour pictures, using different colours to code the emission in each infrared band. These are proving particularly popular with journals and authors of books but here unfortunately only monochrome images can be reproduced.

David A Allen
Anglo-Australian Observatory



Left:

The rings of Uranus. At a wavelength of 2.2 μm, methane in the atmospheres of the giant planets absorbs incident sunlight, thereby dimming the planets greatly. In the case of Uranus, the reduced glare of the planet permits us to image the slender rings that encircle it. These are extremely faint features, and in this picture the presence of noise has rendered both planet and rings rather blotchy. The planet is seen here from almost above its pole, so that the rings are seen as a bright circle distinct from Uranus itself.

Jupiter at two infrared wavelengths. In the light of methane, Jupiter has a very different appearance from that in the visible. In the left image, at 2.2 μm, portions of the planet which are deficient in methane appear bright. In such places a higher layer cloud (probably ammonia) overlies the methane atmosphere. Note how the poles are bright. At right is an image taken at 4.8 μm. Now we see through the upper cloud layers to deeper regions which are warmer. Thermal radiation is recorded at 4.8 μm rather than reflected sunlight.