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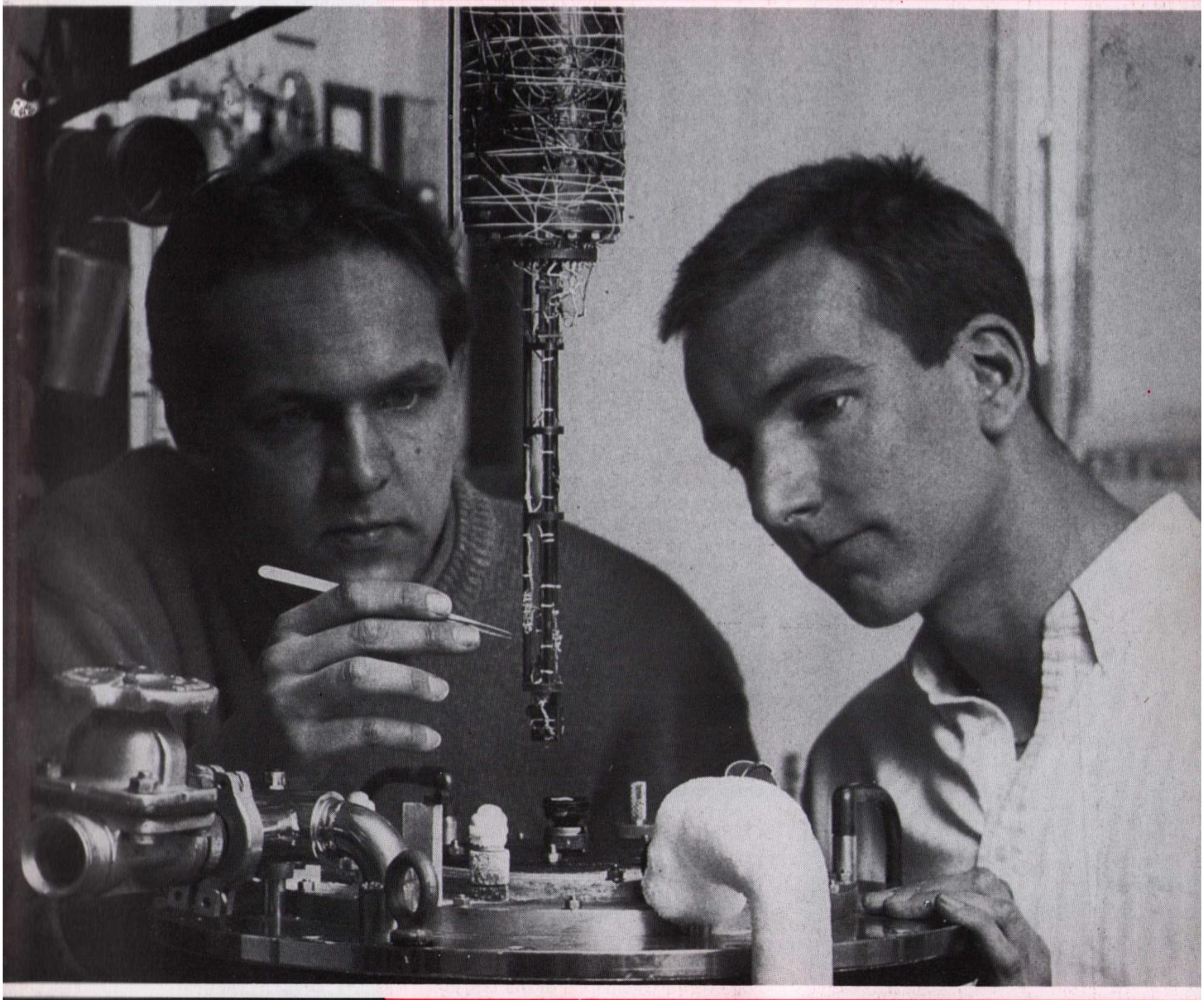

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The Science and Engineering Research Council is one of five research councils funded through the Department of Education and Science. Its primary purpose is to sustain standards of education and research in the universities and polytechnics through the provision of grants and studentships and by the facilities which its own establishments provide for academic research.

Establishments of the Science and Engineering Research Council

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SERC *Annual Report* (available through bookshops) gives a full statement of current Council policies together with appendices on grants, awards, membership of committees and financial expenditure. ***SERC Bulletin,*** which is normally published three times a year, summarises the Council's policies, programmes and reports.

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Front cover picture

N P Hewett (left) and P A Russell with equipment used to study the angular and frequency distributions of the phonons emitted from a heated two-dimensional electron gas in the Quantum Hall regime. This is one of several phonon experiments within the Nottingham NUMBERS project on Low Dimensional Structures.
SEE PAGE 22.

The future of the UK in CERN

During 1987, the scientific press was full of reports that the UK Government was thinking of pulling out of CERN, the European Particle Physics Laboratory, unless the costs of UK participation could be substantially reduced.

The final report of the CERN Review Committee, headed by the distinguished French physicist Professor A Abragam, was presented to the CERN Council in December 1987. This review was undertaken, essentially, at the instigation of the UK. Commenting on the Abragam Report at the December CERN Council, Professor Bill Mitchell, Chairman of SERC and leader of the UK delegation said:

"The UK wishes to remain a full and active member of CERN, provided that a sound basis for doing so can be established.... It will remain a concern of the UK to ensure that the scientific excellence of CERN is continued. At the same time, however, we shall be seeking to ensure that the future cost of CERN is at a level compatible with other priorities, both domestic and international.... We would thus wish to secure, in conjunction with other member states, that conditions exist here at CERN for the best management practices to be promoted and for detailed consideration to be given to the question of widening the membership base to include non-European states.... It will be of the greatest importance to agree on the detailed arrangements needed... both to plan implementation of immediate changes and to consider the numerous matters recommended by the Review Committee for further consideration.... Professor Abragam's report gives a basis for a better managed CERN."

Final decisions on the recommendations in the report should be taken at an extraordinary meeting of the CERN Council in October 1988.

The Nuclear Physics Board believes that continued participation of the UK in CERN is of crucial importance for high energy particle physics in the UK. No less than half the Board's community of particle physicists is involved in CERN, either in experiments on existing accelerators or in preparations for experiments on the 100 GeV Large Electron Positron Collider (LEP), which is scheduled to begin operations in 1989 and in which the UK will have invested about £240 million. The Board has advised the Council, having studied the Abragam Report in detail, that implementation of its direct recommendations, and of reforms derived from it, could result in savings of the order of 20% in the UK's contribuition to CERN in the medium term. However, it has also warned that these savings could be totally eroded unless the Science Budget continues to receive compensation for adverse movements in the exchange rate of sterling against the Swiss franc.

1988 will be a time of feverish activity both within CERN, as the CERN management develops practical schemes for implementing the various agreed changes in the management and operation of CERN (chief among which will be making arrangements for the early departure of at least 300 selected staff), and for the administrators and delegates of the 14 member states whose task it will be to prepare for and/or undertake the negotiations that will be necessary before reforms can be implemented in the governance and financing of CERN and in its relationships with non-member states. First indications are of a desire on the part of all member states to make real and rapid progress towards establishing the future viability of CERN and ensuring its continuity. The signs are therefore encouraging that the 'sound basis', which Professor Mitchell spoke of as essential for continued and full participation in CERN, will be established before the end of this year.

A review article, 'The UK at CERN' by Professor J D Dowell FRS, appeared in the *SERC Report for 1986-87*. This recounts the significant contributions that UK physicists and engineers have made to CERN over the years, including the part they played in the work that led to the award of the 1984 Nobel Prize for Physics to Professors Rubbia and van de Meer for the discovery at CERN of W and Z bosons.

Congratulations to:

Professor George Kalmus, Head, Particle Physics Department, RAL who has been elected a Fellow of the Royal Society; and his brother **Professor Peter Kalmus,** Queen Mary College, London (and RAL) and **Professor John Dowell** FRS, Birmingham University, who have been jointly awarded the Rutherford Medal and Prize. Both have served on SERC's Nuclear Physics Board (Professor Dowell as Chairman) and CERN Committees.

New Senior Management structure in SERC

SERC has restructured the operations at its Swindon Office. Two senior staff, Dr J A Catterall, Secretary to Council, and Mr J B Visser, Director Administration, have retired and, in a new management structure under the Chairman of Council, three Directors have been appointed. They are:

Mr Tony Egginton, Director Programmes, responsible for the 'local' functions of the Swindon Office including the support of the peer review system and special Directorates;

Dr Antony Hughes, Director Laboratories, responsible for the coordination of the work of the Council's Laboratories and Observatories;

Mr John Merchant, Director Council Policy and Administration, responsible for 'federal' and 'headquarters' functions of the Swindon Office, including the Council Secretariat, policy, planning, council-wide administration and public relations.

The Chairman of Council and the three central Directors form the Council's Management Board. The Director Programmes will deputise for the Chairman of Council in his absence. The Director Council Policy and Administration will act as Secretary to Council.

Swindon Office (formerly known as Central Office) will house all three directorates.

The new management structure incorporates the following features:

- a clear distinction in the Swindon Office between those units acting in a 'Council-wide' role and those in a 'local' role;
- the coherence of the 'local' role and the collective identity of those involved;
- simpler lines of communication;
- the overall coherence of Council establishments as part of one entity with flexibility between them;
- the achievement of flexible and speedy, comprehensive and comprehensible responses to other Councils, the Advisory Board for the Research Councils, and national and international partners;
- the identity of policy and planning roles.

The Programmes Directorate includes the following former Central Office Divisions:

Astronomy and Planetary Science Division, including BNSC
Nuclear Physics Division
Science Division
Engineering Division
Special directorates and LINK
Postgraduate Training and Support Section
plus local administration and finance sections.

Although the activities carried out at the Swindon Office will be controlled separately through the respective directors, in the interests of good management certain common services will continue to be run for the whole Office.

(Continued overleaf)

The objectives of the Swindon Office

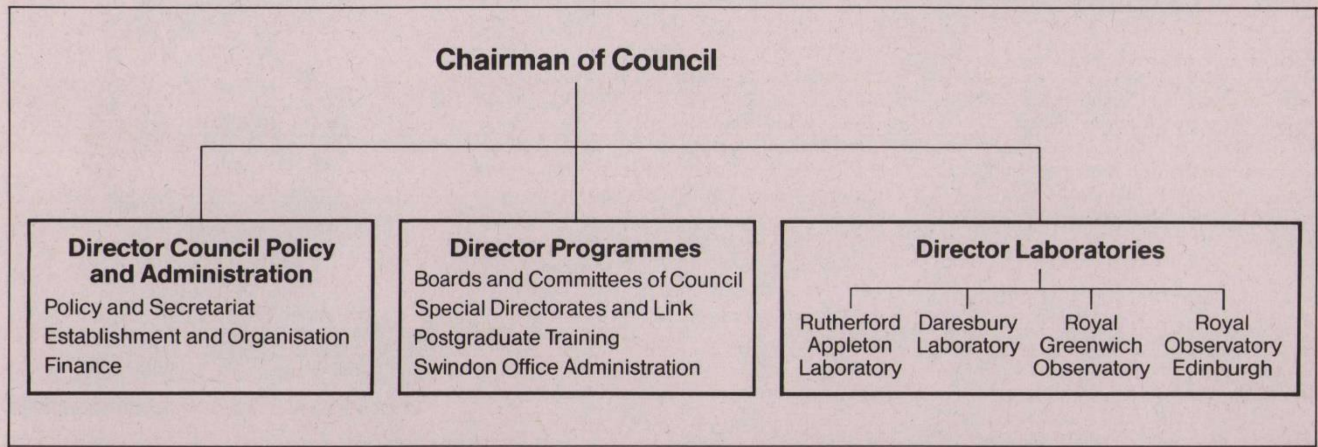
(a) to administer the grant-in-aid for the benefit of science and technology in the UK;

(b) to set up and operate a peer review system and to pursue the recommended work in universities and polytechnics or in Council's own establishments;

(c) to provide the senior management focus for the operation of the establishments;

(d) within (a) to provide the overall financial and manpower control;

(e) within (a) to provide the mechanisms, and the inputs for policy formulation by Council.

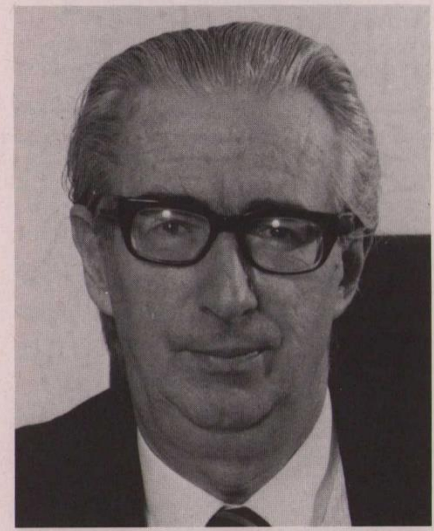


The revised management structure for SERC's Swindon Office

New Senior Management structure in SERC

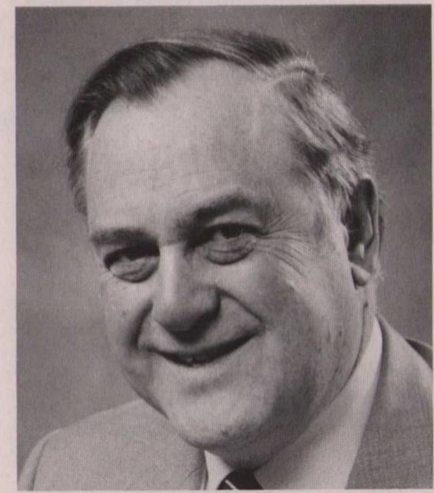
Director, Programmes

Tony Egginton, aged 57, worked as a research assistant at Harwell before joining the Rutherford Laboratory in 1961 to work on the accelerator NIMROD. In 1965, Mr Egginton became Head of Operations on the NINA accelerator at Daresbury Laboratory in Cheshire. He became Head of Engineering Division in the Council's London Office in 1972 and in 1974 was appointed to the post of Director Engineering and Nuclear Physics. Since that date his responsibilities at Director level have varied with the changing emphasis in Council policy and new initiatives.



Mr Tony Egginton

Director Laboratories



Dr Antony Hughes

Tony Hughes, aged 46, is at present the United Kingdom Atomic Energy Authority's Chief Scientist and Director of Nuclear Reactor Research at the Authority's Harwell Laboratory. He joined the Atomic Energy Research Establishment, Harwell, in 1963 and was involved for many years in materials research, as group leader in the Materials Development Division and then head of the Materials Physics and Metallurgy Division. He became the Authority's Programme Director for Underlying Research and Director of non-Nuclear Energy Research at Harwell from 1986 to 1987 when he was appointed to his present post. He joins SERC on 20 June 1988.

Director Council Policy and Administration

John Merchant, aged 43, is currently the Principal Establishment and Finance Officer of the Crown Prosecution Service, a post he has held since 1984; he will take up his new appointment during July 1988. He holds degrees in chemistry and statistics and, in 1970, after four years in management with Lyons Bakery, he became a lecturer in statistics and operations research at Cranfield Institute of Technology, moving from there to the Ministry of Defence as a statistician in 1975. He joined the Civil Service College in 1979 as Director of Statistics and in 1982 was appointed head of the Personnel Department in the Cabinet Office that dealt with the central management of scientific, professional and technology and other specialist civil service grades.

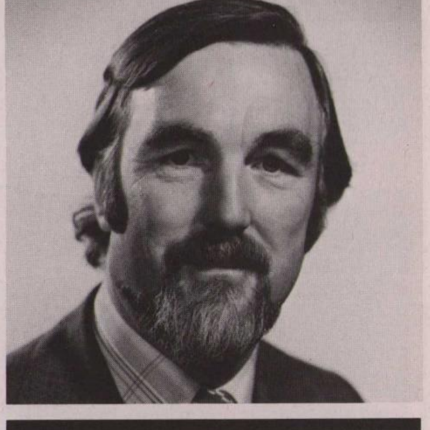
Mr John Merchant

Other new appointments

From 1 July, **Dr H H Atkinson**, currently Director Science, will become Director with special responsibilities. He will report directly to the Chairman of Council and will be responsible for advising Chairman and the Management Board on long-range policy options and for such other projects and duties as required.

Other new appointments as a result of the management restructure are: **Dr David Clark** as Deputy Director Programmes; and **Dr Ron Newport** (formerly Rutherford Appleton Laboratory) who succeeds Dr Clark as Head of Science Division.

In addition, the appointment of **Professor Alan Leadbetter** as Director of Daresbury Laboratory has been announced and that of **Dr Gordon Walker** as Deputy Director of Rutherford Appleton Laboratory has been confirmed. Professor Leadbetter, who is at present an Associate Director and Head of the Science Department at RAL, will succeed Professor Leslie Green on 1 September 1988, on the latter's retirement.



Professor Alan Leadbetter

Council commentary

PES settlement

The 1987 Public Expenditure Survey provided additional funds to SERC for the financial year 1988-89, including compensation for recent salary increases awarded to university staff. Without these extra funds, the volume of new work which the Council could have supported next year would have been severely restricted. This arises because the cost of staff whose salaries are paid from existing SERC research grants would have increased sharply, absorbing a large proportion of next year's uncommitted funds. Further additional funds made available to SERC for 1988-89 have allowed the Council to make a start on two important new initiatives — the Interdisciplinary Research Centres (see page 4) and LINK (see page 6) and to join the European Synchrotron Radiation Facility. The Council's allocation from the Science Budget for 1988-89 is £366.284 million.

Opportunities and prospects

At the Council meeting in February, the main item of business was finalising the 'Forward Look' plan for the four financial years starting in April 1989. This plan, which is an account of the intended deployment of resources within existing provisions together with bids for additional funds for new developments, has now been submitted to the Advisory Board for the Research Councils.

An increasing proportion of the Council's research grant funding will go into the strategic research being pursued under new initiatives, but additional funds will be needed to ensure the impact at the national level that is the objective. All four of the Council's Boards put forward proposals under these headings and in other areas for additional activities that would require more money, and it was clear that only a small proportion of these, timely and promising as they were, would be likely to be supported. The Council decided on a further redistribution of resources away from nuclear physics and astronomy towards science and engineering. The resultant flexibility will enable some relief to be given to future allocations for research grants in science and engineering, where the overall 'success rate' for applications is now at a disturbingly low level: in the 1986-87 session, SERC support had fallen to 20% or only £1 of every £5 being sought for research in these areas.

International subscriptions

At its December meeting, Council approved our national payments to the following international organisations for the coming year:

European Space Agency (science programme): £22.38 million
European Science Foundation: £192,000
Institut Laue-Langevin: £8.76 million
European Incoherent Scatter radar facility (EISCAT): £463,000

The question of UK membership of CERN will be further reviewed by Government in the course of 1988 and future provisions for the UK contribution within the SERC budget will depend on the outcome (see facing page).

Biotechnology review

Council has established an independent review body for biotechnology, to be chaired by Professor Tom Blundell (Birkbeck College). This committee has been charged with reviewing the achievements of the SERC Biotechnology Directorate since its creation in 1981 and advising on SERC's future role and activities in this area.

A national electronics research initiative at RAL

National electronics research initiatives (NERIs) are programmes supported by the Department of Trade and Industry of collaborative research activities in fundamental areas of electronics, based on suitably equipped centres. The Council has approved the establishment of a NERI in electron beam lithography at the Rutherford Appleton Laboratory, which has considerable experience and expertise in the techniques involved.

Visiting committees

Three visiting committees have been appointed, one to cover Rutherford Appleton and Daresbury Laboratories; one the Royal Greenwich Observatory and the Royal Observatory, Edinburgh; and one the Swindon Office. They will be concerned with general running of the establishments and not with scientific programmes. The committees will report annually to Council.

Secretary of Council

Dr Catterall retires as Secretary of Council in May 1988. He will then become Secretary of the Institute of Metals, in succession to Sir Geoffrey Ford, who is also retiring.

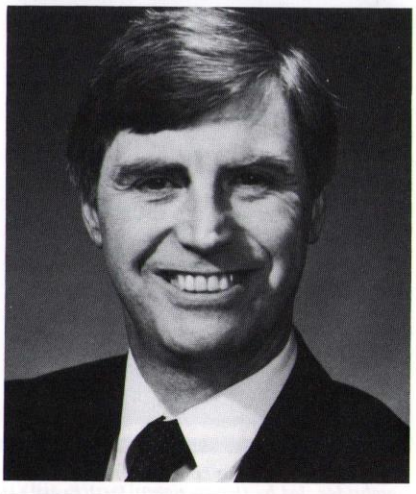
New head for Teaching Company Scheme

Professor Stephen Humble has been appointed the new Director of the Teaching Company Scheme (TCS), from 1 April. This Scheme was launched in 1975 by SERC and the Department of Trade and Industry (DTI) to develop active links between academic institutions and industry. It is now also supported by the Economic and Social Research Council and the Northern Ireland Department of Economic Development. The Scheme currently supports more than 300 programmes between industry and universities and polytechnics, and is due to be expanded substantially over the next few years. It also forms part of the DTI Enterprise Initiative.

Stephen Humble, aged 44, is Professor of Operational Research and Statistics at the Cranfield Institute of Technology (the Royal Military College of Science). He has also been Vice Principal and Chairman of the School of Defence Management since 1985.

Commenting on his appointment, Professor Humble said:

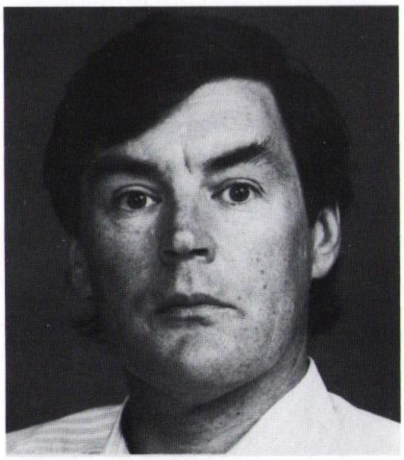
"The Teaching Company Scheme represents a major step forward in developing partnerships between the nation's wealth creators and our knowledge creators. I am delighted to be given the opportunity to direct the future growth of this process. I believe it can have a major impact on the success and profitability of British industry in the coming decades. It must also have an important influence on the way higher education responds to the needs of industry and hence how it prepares our graduate engineers and managers for their future careers."



Professor Stephen Humble

Superconductivity and Britain's first Interdisciplinary Research Centre

Cambridge University is to be the site of Britain's first Interdisciplinary Research Centre. The Council announced this decision after its December 1987 meeting and, in February 1988, announced three further centres (see page 5). The Cambridge Centre, in high temperature superconductivity, was recommended by the joint SERC/ Department of Trade and Industry National Committee for Superconductivity, chaired by Sir Martin Wood of Oxford Instruments. Membership of the Committee reflects the whole spectrum of both academic and industrial interest in superconductivity, and the intention is to encourage the establishment of links between academic and industrial research partners.



Dr Ian Corbett, National Coordinator for the superconductivity research programme

The development of research in the area of high temperature superconductivity is of strategic importance to industry, and the potential for commercial exploitation is great. However, the realisation of the wide range of possible applications will depend on extensive basic research. The potential for multidisciplinary research, which has often been the source of the most promising developments, is particularly great in the area of superconductivity, a fact reflected in many of the applications received so far, which have cut across the traditional departmental boundaries.

Dr Ian Corbett, Head of Applied Science at the Rutherford Appleton Laboratory, has been appointed jointly by SERC and DTI as the National Coordinator for Superconductivity; his brief includes the encouragement of further industrial-academic collaboration and keeping in close touch with developments abroad. A strategy document has been circulated, which outlines the proposed organisation of the national programme, and the support of research through SERC and DTI.

A key aspect of this strategy is the creation of an Interdisciplinary Research Centre for superconductivity at Cambridge. Commenting on the announcement of this the Secretary of State for Education and Science, Mr Kenneth Baker, said that he welcomed the development as an important initiative by SERC in this area of scientific and technological interest, and that he would watch the progress of the Centre with great interest. The Centre is expected to receive SERC support for the next six to ten years, provided through the award of a rolling grant. An initial grant of £5.3 million over six years has been approved; a review of resources will take place after the first two years of operation, followed by a major review after four years, at which time the decision will be taken whether to extend the grant.

Five major departments contribute to the new High Temperature Superconductivity Research Centre at Cambridge, led by (left to right): Dr J Evetts (Materials Science), Dr A M Campbell (Engineering), Dr Y Liang (Physics), Dr P P Edwards (Chemistry) and Dr E Salje (Earth Sciences). (Photo: Cambridge University)

The new Centre is to draw on the existing strengths of five major departments at Cambridge — Physics, Chemistry, Materials Science, Engineering and Earth Sciences — combining both basic and applied research. The research will be undertaken by a group of world-class scientists with proven track records in superconductivity; the quality and experience of the multidisciplinary team of researchers at Cambridge who will devote their time to the work of the Centre was a major influence on the choice of the site.

Collaboration with other universities and with industry will be an important part of the successful operation of the new Centre, and Visiting Fellowship awards will be available for the benefit of UK research workers who wish to undertake research there.

In addition to support for the Centre, £2 million is available from SERC this session for grants for work outside the Centre. More than 50 applications totalling some £14 million were received for consideration by the Committee this round; 11 grants were approved, including three rolling grants to be awarded to Birmingham and Warwick Universities and Imperial College of Science and Technology. £900,000 remains for commitment at the forthcoming round. Prospective applicants should discuss proposals with the coordinator, Dr Corbett, before submission. He can be contacted at the Rutherford Appleton Laboratory, telephone Abingdon (0235) 446239 (direct line).

Esther Peacock
SERC, Swindon Office

Three more IRCs announced

Interdisciplinary Research Centres are to be set up in engineering design, surface science, and molecular sciences, to be based at Glasgow, Liverpool and Oxford Universities respectively. This was announced after the Council meeting on 10 February. These three Centres are in addition to that at Cambridge in high temperature superconductivity agreed by Council in December 1987 (see facing page). The purpose of the IRCs is to provide a focus for the development of research programmes in interdisciplinary topics of strategic importance.

The announcement of these three Centres is the culmination of a process in which the Council considered some 80 bids for Centres in seven strategic areas of science and engineering. All the bids were of high quality and many were excellent. The Council's intention is that, within its limited existing funds, at least some of the proposals of the highest quality, which could not be accepted as IRCs now, should be supported where possible by other mechanisms.

Of the four IRCs supported, about half of the funds are to be found from the Council's own resources, and half from new money allocated by the Advisory Board for the Research Councils. The awards are subject to approval by the Department of Education and Science and further discussions with the institutions concerned.

The Council also wishes to establish an IRC in synthesis and characterisation of semiconductor and novel materials, for which it also received excellent bids and it has chosen the London consortium based on Imperial College of Science and Technology (ICST). The starting time, however will depend on the availability of funds and SERC will discuss the best way forward with ICST.

The Council is at present considering what topics might be appropriate for a further group of IRCs to be decided in a year's time. However, for such a second round, the Council would require extra funds.

Engineering design

This Interdisciplinary Research Centre will be based on a Scottish consortium comprising Glasgow, Heriot-Watt and Strathclyde Universities and Napier and Paisley Colleges.

The Council aims to create a world-class design research centre which should help industry generally to compete better in a world market where good design is a prerequisite for good sales. It fully accepts the need to shorten the time taken for the most advanced technology to be applied in industry and sees the IRC in Engineering Design as a vital link in this process.

The Scottish consortium was chosen because the Council was impressed by the quality of the proposal together with the degree of support pledged by the collaborating institutions, their obvious willingness to work together, their existing interest in design and their close links with industry, for example in electromechanics and offshore engineering.

The Centre, which will have a threefold structure for research, industrial projects and education and training, will be based at Glasgow University with satellite research groups and workstations at the collaborating institutions. A comprehensive distributed computer network will be used to maintain close links between the Centre and the satellite design groups and with major industrial partners, giving the members of the consortium an unrivalled capacity for advanced engineering design work.

The Centre is expected to have a major impact on local industry. In its catchment area there are a large number of small and medium-sized firms needing access to advanced design expertise backed by the most modern engineering facilities. It is expected that funding from SERC will be augmented by support from other bodies and from industry.

Surface science

An Interdisciplinary Research Centre in Surface Science is to be established at Liverpool University, involving collaboration with Manchester University. The Centre will work closely with the related activities in the Leverhulme Centre for Innovative Catalysis at Liverpool University, and will make extensive use of the Synchrotron Radiation Source at SERC's Daresbury Laboratory. The main objectives of this proposal are:

☐ to create an interdisciplinary research centre with a high international reputation, and to act as a focal point for national activity in surface science;
☐ to produce a coordinated programme of experimental and theoretical research on the behaviour of well characterised surfaces of metals, oxides and semiconductors, including the geometrical structure of these surfaces, their electronic structure, lattice dynamics and the dynamics of their interaction with gaseous species:
☐ to exploit improving understanding of surfaces in support of the industrial applications of surface science;
☐ to liaise closely with the UK-based scientific instrument companies in the development of surface science instrumentation; and
☐ to be a major training ground for students.

Molecular sciences

Oxford University is to be the site of a Centre in Molecular Sciences. The programme of the Centre is based around the study of proteins and their interactions with other molecules to control biological functions. Particularly important problems to be tackled are protein folding and specificity; blood clotting and fibronolysis; immunology; signal transduction; viruses; and enzymes of secondary metabolism. Discussions about a joint funding mechanism with the Medical Research Council are taking place; the funding will be determined in the light of these discussions and of negotiations with Oxford University.

European cooperation on High-T_C superconductivity

Measures to enhance the effectiveness of European research into high temperature superconductivity were announced in March. They were agreed at a meeting of representatives of SERC, CNRS (France), CNR (Italy), and DFG and MPG (West Germany), held in Paris to discuss their national research programmes on high temperature superconductivity. The measures cover the exchange of information, funding for staff exchanges, and organisation of specialist scientific meetings.

The agencies have formed a Standing Committee to assist them. Dr Ian Corbett, the National Coordinator for Superconductivity, will represent SERC on this committee.

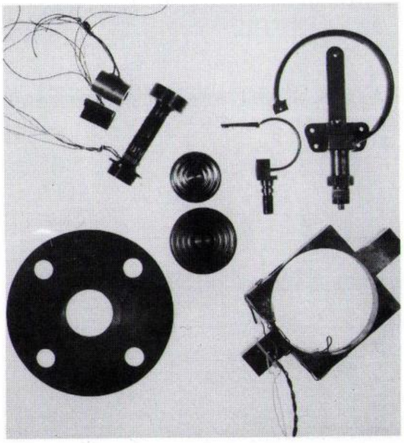
LINK : bridging the gap between science and the market place

A new scheme to promote strategic collaborative research, and to facilitate the transfer of knowledge from research to the point where it can be exploited in industry, came into operation in February with the announcement of the first approved LINK Programmes. LINK is designed to:

☐ foster priority areas of research directed to the development of innovative products;
☐ stimulate a real increase in industry's own investment in R&D;
☐ strengthen the links between industry, higher education, the research councils, and other research establishments; and
☐ develop technologies that cross the boundaries of industrial sectors and scientific disciplines.

LINK involves all the research councils and the major government departments and covers the full breadth of science and technology. The scheme is overseen by the LINK Steering Group (LSG), made up of senior industrialists and representatives of Government, higher education and other research institutions, and chaired by Mr Robert Malpas, a managing director of BP plc.

Individual LINK programmes are endorsed by the LSG and will be managed by the government department or research council with primary interest in the programme. Each programme will run for three to five years, and will be made up of a number of LINK projects each running for one to five years. Projects will involve one or more companies in collaboration with higher education institutions, although government research laboratories, including research council establishments, may also participate directly in appropriate projects. The Government will fund up to 50% of each project, through existing mechanisms, with the balance of funding coming from the industrial partners. Public funding for a particular project may be drawn from more than one goverment department or research council. All companies trading in the UK are eligible to participate in the scheme, and small firms will be particularly encouraged to participate in LINK.



Industrial measurement systems: Using CAD techniques developed at City University, companies are already designing transducers, sensors and systems better and faster than before.

Brief details of programmes approved to date which involve SERC participation are given below. A Nanotechnology Programme, in which SERC is not involved, has also been approved.

Molecular electronics

This is a £20 million programme, supported jointly by SERC, the Department of Trade and Industry (DTI) and industry for the systematic exploitation of molecular, including macromolecular, materials in electronics and related areas such as optoelectronics. Emphasis within the programme will be placed on materials with the potential for active functions:

organic metals and semiconductors
non-linear optical materials
liquid crystal materials
photochromic and electrochromic materials
piezoelectric and pyroelectric materials.

Support will also be available for enabling technologies such as Langmuir-Blodgett films and relevant studies of electronic, photonic and ionic conduction processes.

For further information contact Stuart Ward (ext 2173) or the LINK Molecular Electronics Programme Secretariat (ext 2166), at SERC Swindon Office.

Advanced semiconductor materials

This £24 million programme, supported by SERC, DTI and industry, aims to improve the performance of microelectronic devices by making available better materials and fabrication methods. Although a materials programme, it will be device-led, using device-performance criteria in assessing the success of the materials technology developed. Consequently, a limited amount of device research will be included in the programme. Primary topics include multilayer structures, and devices using these; III/V, IV and II/VI bulk materials, excluding bulk silicon, as substrates for epitaxial growth; and processes and equipment for multilayer structures or special materials.

For further information contact John Monniot (ext 2272) at SERC Swindon Office or the LINK Advanced Semiconductor Materials Programme Secretariat, DTI, Kingsgate House, 66-74 Victoria Street, London SW1E 6SW; telephone 01-215 2749.

Industrial Measurement Systems

The £22 million IMS programme, supported by SERC, DTI and industry, aims to develop advanced integrated instrumentation and measurement systems. The programme will focus on three main areas: microelectronics; optical and spectroscopic instrumentation; and sonics and ultrasonics. Primary topics include real-time signal processing, data transmission, data analysis, and the integration of these into systems.

For further information contact Phil Hicks (ext 2401) or the LINK IMS Programme Secretariat (ext 2159) at SERC Swindon Office.

Eukaryotic Genetic Engineering

The £4.7 million EGE programme, funded by SERC, DTI and industry, aims to increase the understanding of the molecular genetics of yeasts, fungi, plants and animals, including plant and mammalian cells in culture. Primary topics include identification of genes, genetic transfer, identification of switches and triggers controlling the expression of genes and the development of novel vectors.

For further information contact Dr Maurice Lex (ext 2410) at SERC Swindon Office or the LINK EGE Programme Secretariat, Laboratory of the Government Chemist, Cornwall House, Stamford Street, London SE1 8XY; telephone 01-211 8876.

In all cases these programmes are targeted at areas of pre-competitive research exploitable in the medium term after further development within the appropriate industry. Further programmes are under consideration.

If you would like more information regarding LINK generally, contact:
S D Ward
LINK Coordinator (ext 2173)
P D Tomsen
LINK Unit (ext 2162)
SERC Swindon Office

Transputer Initiative National Support Centre opened

The Joint SERC/Department of Trade and Industry Initiative in the Engineering Applications of Transputers was launched in April 1987.

The main objectives of the Initiative are:

- to provide awareness of the potential of the transputer and its associated technology and applications to the solution of problems requiring parallel processing;
- to use expertise within the academic community to develop a viable software base, which is regarded as being essential for the exploitation of parallel processing systems in industry;
- to promote high quality research using transputers;
- to facilitate technology transfer to UK industry.

The National and five Regional Support Centres are now established, including a Regional Centre for Northern Ireland as the result of a special agreement under which the Department of Economic Development will be funding half the Initiative's share. The Centres are located as follows:

National and North East
Sheffield University and Sheffield City Polytechnic
Director: Professor D Lewin

Northern Ireland
Queen's University of Belfast and Ulster University
Director: Dr M E C Hull

North West
Liverpool University
Director: Professor W Eccleston

South, South West and South Wales
Southampton University
Director: Professor A J G Hey

Scotland
Strathclyde University
Director: Professor T Durrant

London and South East
Rutherford Appleton Laboratory
Director: Dr M R Jane

The National Support Centre, based at the Sheffield Science Park, was officially opened on 7 March 1988 by Mr Robert Jackson, Parliamentary Under Secretary of State for Higher Education and Science. Official openings of the Regional Centres were due to take place during April, May and June.

The Support Centres will each act as a focal point for transputer-related activities in their areas. They will be the prime points for interface between industry and the Initiative, although they will also be available for use by the academic community. They will provide a programme of courses and tutorials; a hands-on service and assistance; and a telephone hot-line 'help' service.

The National Support Centre will fulfil all these functions and will in addition operate a software-exchange library for the Initiative. As groups in the community develop software packages which they are willing to make freely available for R&D purposes, these will be added to the software library. It is envisaged that the provision of maintenance and support will be a matter for negotiation between the originators and the National Centre, while the rights for any commercial exploitations would normally be retained by the originators.

Sheffield City Council is developing the Sheffield Science Park in partnership with English Estates. The Park is supported by central Government and the EEC and is already an active member of the United Kingdom Science Park Association (UKSPA). The Transputer Centre was the Park's first resident. The Science Park's management company reflects the partnership of interest, with representatives from Sheffield City Council, English Estates, Sheffield City Polytechnic, Sheffield University, BSC (Industry) Ltd, ASTMS, Technor Ltd and Midland Bank.

Dr M R Jane
Rutherford Appleton Laboratory

At the official opening in Sheffield, left to right: Clive Betts, Leader of Sheffield City Council; Ian Draffan, Head of Computer Studies, Sheffield City Polytechnic; Dr Mike Jane, RAL; Dr Ashley Catterall, Secretary, SERC; John Stoddart, Principal, Sheffield City Polytechnic; Professor Geoffrey Sims, Vice Chancellor, Sheffield University; Professor Doug Lewin, Director of the National Transputer Support Centre; Robert Jackson MP; Dr Paul Williams, Director, RAL.

X-ray diffraction recording for materials

The Polymer Physics Group in the Physics Department of Bristol University has been using detector technology originally developed for particle physics in their X-ray diffraction work, to help to understand the structure of polymers, particularly those which are crystalline. The work, which has been supported by the Materials Committee, is described here by Andrew Keller and David Sadler of Bristol University.

First a few remarks about polymer crystallinity and its significance. Many familiar plastics (long chain molecules, polymers) are partly crystalline, and their properties can be modified dramatically, depending on the way the crystallisation proceeds. In order to optimise properties such as stiffness and toughness, it is important to characterise the range of different structures which are obtainable, and to understand how and why they occur.

This understanding presents some fundamental puzzles, drawing on many branches of physical science: the pursuit of the subject represents a whole microcosm of scientific activity. On the one hand the subject itself is of basic academic interest centred on the need to understand long-chain molecules in terms of general principles, while the methodology relying on counters provides a link with other branches of pure science, such as particle physics. On the other hand the subject matter has many practical outlets essentially concerned with improvement of materials for diverse technological and commercial applications.

To a large extent, structure studies rely on using radiation scattered by the material investigated. The results are retrieved either by measuring the scattering directly (for example X-ray diffraction) or by focusing the radiation into an image (optical and electron microscopy are examples).

Structure features of principal interest for crystalline polymers above the molecular level are fibrils and crystallites frequently about 10-100 nm in size. The usual way to explore this size range is either by X-ray scattering at small angles (a few degrees) or electron microscopy. The former has several advantages, in spite of not obtaining an image directly: for example *in situ* measurements can be made during heating and cooling. Such 'kinetic' measurements put a premium on fast data collection. An important means to increase speed is the use of so-called position sensitive detectors (PSD) which are sensitive to irradiation at a range of angles of incidence simultaneously. Each detection event is coded electronically, and sorted into memory according to its angle. In Bristol, a prototype PSD has been in operation since 1974, and the project on which a recent report to SERC is based replaced this with a new PSD designed and assembled at the Rutherford Appleton Laboratory under the direction of Dr E Bateman.

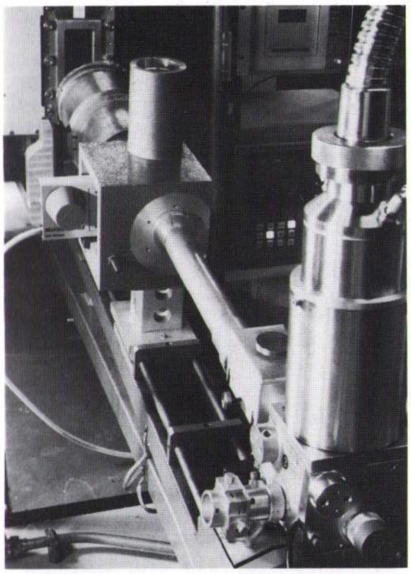


Figure 1: The small angle X-ray equipment, using an optical bench: from bottom right to top left are the X-ray generator tube, a unit for focusing the beam into a narrow solid angle, the sample position with temperature controller, a vacuum tube, and the detector.

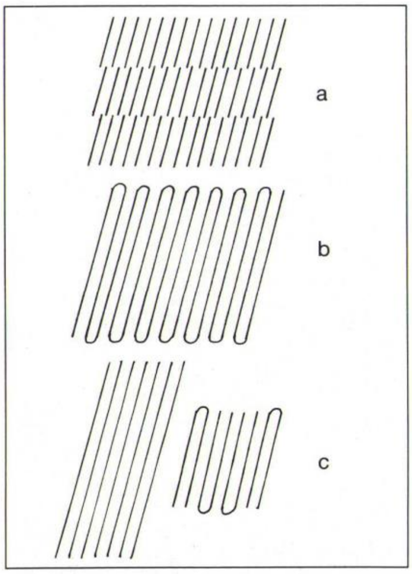


Figure 2: Schematic representation of (a) rod-like non polymer molecules; (b) long-chain polymer chain, and (c) 'oligomeric' short-chain molecules.

Currently the fastest data acquisition is through the combination of using PSD with synchrotron radiation sources (in this country, at Daresbury) involving timescales often in the region of milliseconds. This can be compared with small-angle X-ray scattering measurements as traditionally performed using photographic film or detectors sensitive to one angle at a time, which may require up to several days. PSD on laboratory X-ray sources provides a useful intermediate facility (using a timescale of seconds or minutes) between the traditional X-ray recording and the scarce and expensive large-scale central facility such as the synchrotron source. In addition to extending the capability of the latter, it makes its utilisation more effective through enabling in-house selection of the most profitable experimental conditions and sample type for examination during the precious short times available at the synchrotron source (itself usually at some distance from the user's laboratory, requiring a special journey by the experimenter).

The camera and detector are shown in figure 1. The distance from sample to detector depends on the angular range required, the longest distances being required for the smallest angles. Some of the associated electronics and an output 'spectrum' can be seen at the centre and top. This apparatus has been used during the course of a wide range of investigations, often in combination with other techniques. The cases where it was particularly central involved chains which are relatively short (oligomers). This is the demarcation line between non-polymers (such as chain molecules) about 1 nanometre long, which crystallise into the usual three-dimensional array as extended rods (figure 2a) and polymers, where the chain repeatedly folds back and forth (figure 2b) to create a characteristic platelet crystal shape (thickness about 10 nanometres). For chain lengths of 10 to 30 nanometres, some intriguing behaviour results from the molecule 'deciding' whether to extend or whether to fold to form a hairpin (figure 2c). A working hypothesis is that folding rather than extension will generally occur if it is allowed thermodynamically.

We have used two types of different material for studying the demarcation between extended and folded chains.

One such study involved poly(ethylene oxides) available as short, even if not strictly uniform, chains, much investigated previously. Our particular contribution was the attainment of crystals much larger than anything seen before in this branch of polymer science (figure 4). In spite of their appreciable lateral dimensions, such crystals are only 10 microns thick and the PSD was able to detect the weak signals arising from such thin crystals (figure 3). This enabled us to conclude that the crystal is made up of a stack of about 100 thin (10 nanometre) sheets — information needed for our continuing pursuit on how polymer crystals are constituted on a supermolecular level.

The second system of our studies on the onset of chain folding are ultralong n—alkanes of chain-lengths that bridge the gap between conventional paraffins and polyethylenes which in everyday life are familiar as waxes and plastics respectively. These materials consist of strictly uniform chains of appropriate lengths synthesised in our Organic Chemistry Department by Professor M C Whiting. The few milligrams we possess of each of the four different chain-lengths synthesised are all that exist anywhere, and hence are of inestimable value. The PSD in itself, and as an in-house preliminary for the programme using the high-flux source at Daresbury, was and continues to be indispensable for extracting information from the minute quantities of material available.

The wealth of information arising and the clarity of the effects cannot be adequately conveyed here in brief. We believe that these results, in combination with those on the more abundantly available but less well defined poly(ethylene oxides) described above, are quite fundamental for the understanding of polymer crystallisation. Among much else, the boundaries between extended and chain-folded crystallisation could not be defined and were shown to be determined both by chain length, and for a given length, by the crystallisation temperature. The chain-folded crystals themselves, after completion of crystallisation (as examined during the first stages of the work), were found to contain the chain in a configuration which corresponded to folding of the chain exactly once, twice, and so on. This implies that both the chain ends and folds are flush at the crystal surface, and that the folds must be sharp and regularly defined. However, the later stages of the work, where the crystallisation was followed *in situ* by high-speed diffraction recording, revealed a series of unsuspected new effects. These show that the initial act of chain deposition leads to a transient stage which transforms into the final state referred to above, where the fold-length is an integer fraction of the chain-length, the transformation taking place still during crystallisation. This transformation can correspond to either an increase of the fold-length (thickening) or to a decrease (thinning). The latter is particularly remarkable as it means that the crystal layer is simultaneously thinning and laterally expanding, through growth along the periphery.

It has become evident that the transient state is associated with a substantial amount of disorder particularly along the fold surface, which is then removed during regularisation accompanying the transformation. Such findings are also important on the conceptual level as they help us to appreciate the coexistence or interrelation of order and disorder within an essentially polycrystalline yet plastic—elastic material features intrinsic to semicrystalline thermoplastics.

The long-chain alkanes show another phenomenon which is probably unprecedented for any crystal growth process: calorimetry shows a minimum in growth rates as a function of temperature. The X-rays show that the crystals are extended chain form at and above, and folded below, the temperature of this minimum. The explanation of this extraordinary effect goes to the heart of our understanding of the folding process: as the temperature is reduced, folding becomes more and more likely, but folded-chain crystals are not yet capable of growing properly. The consequence is a poisoning of the perimeter of an extended chain crystal and a minimum in growth rate.

Professor A Keller and Dr D M Sadler
H H Wills Physics Laboratory
Bristol University

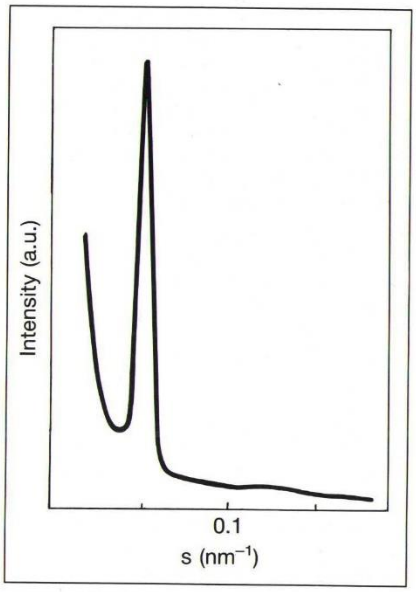


Figure 3: Scattering diagrams of intensity versus s (= 2sinθ/λ where 2θ is the scattering angle and λ the wavelength). The peak corresponds to Bragg diffraction from a stack of layers each 10 nm thick.

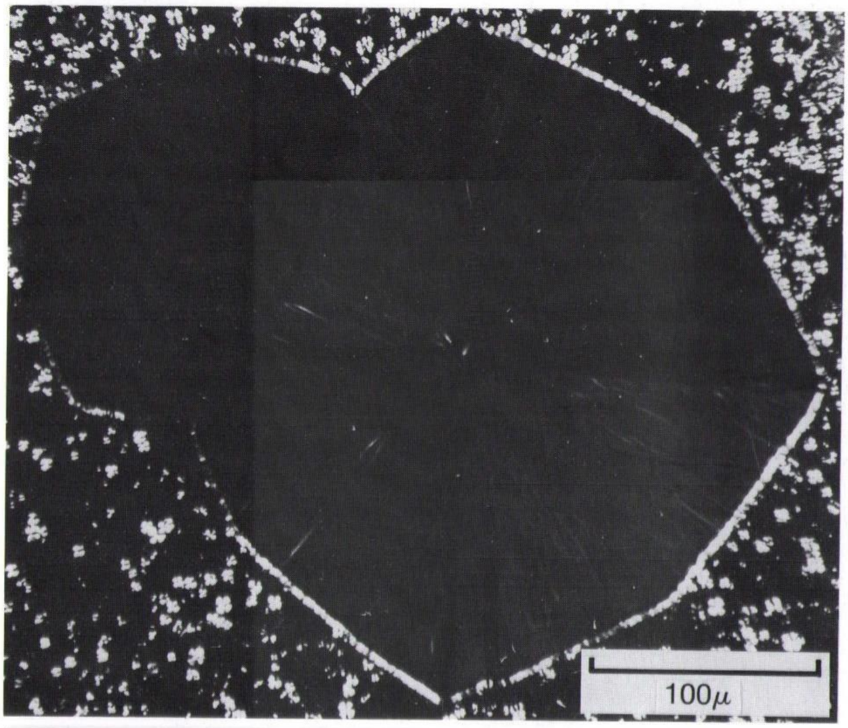


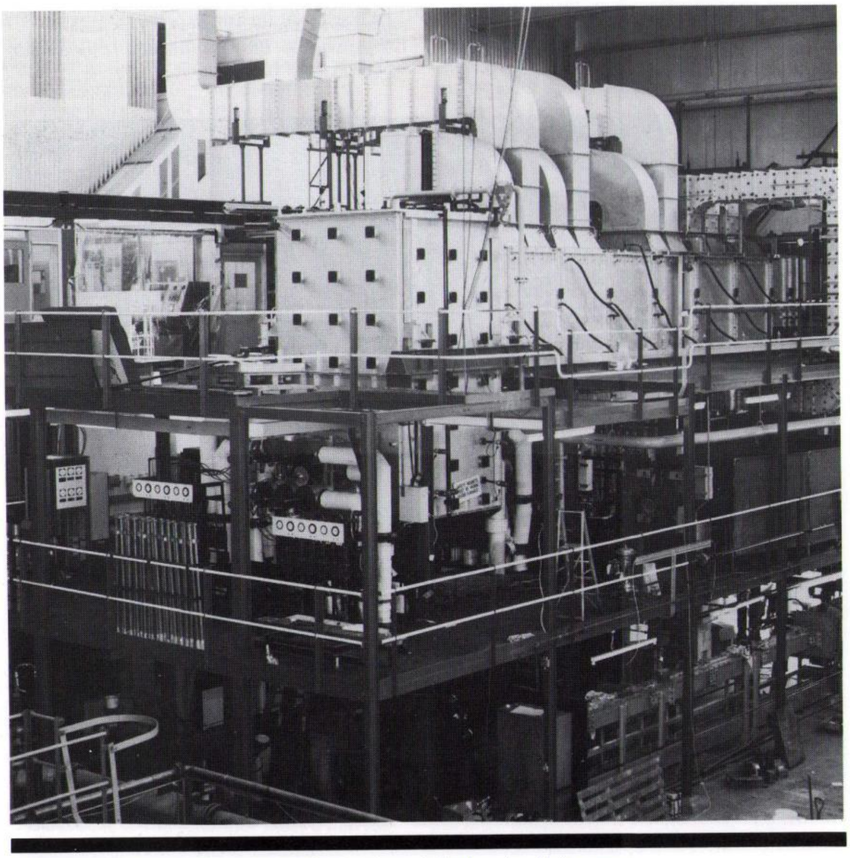
Figure 4: An optical micrograph of crystals defined in figure 3.

SERC-CEGB cofunded research

Over the years, many schemes have been developed by SERC to foster engineering research that is relevant to industry. One of these is *cofunding*. Following a successful initial phase, SERC and the Central Electricity Generating Board have recently agreed on a further three-year programme with the emphasis on certain key areas. SERC and the Technology Planning and Research Division of the CEGB signed an agreement in November 1987 extending the original four-year cofunded programme until 31 December 1990, with a provision for an extension by a further two years.

The objectives of the agreement are to continue and expand the existing coordinated programme of good quality academic research. All the work supported is related to the Board's in-house research activities, thereby ensuring its industrial relevance and good technology transfer, and establishes close personal links between the academic researchers and their colleagues in the CEGB laboratories. An important aim of the new agreement is to involve other industries in at least 30% of the projects, with commitments on their part ranging from offering advice and information to tangible contributions of cash and/or support in kind — manpower, materials, equipment or services. Thus, the spirit of cofunding is seen in the broad context of 'UK Ltd' with benefits to academic institutions, the electricity supply industry and UK manufacturers, in respect of their relative contributions.

It is intended to increase the existing rate of total expenditure of £242,000 a year to £350,000 a year in the financial year 1988-89 and to £500,000 a year thereafter, with SERC and CEGB each contributing half the cost of the research grants. Grants are awarded as standard SERC grants and applications submitted on the usual RG2 form. However, prior discussion of the inclusion of an application with the Cofunding Officer (see below) is essential. A procedure is being introduced for formal approval of a project by the manager of the appropriate CEGB laboratory who appoints one of his staff to act as Technical Correspondent to represent CEGB's interest. The programme will continue to be managed by a Cofunding Panel, comprising three representatives of the CEGB and three academics nominated by SERC.



Furnace modelling facility at CEGB's Marchwood Engineering Laboratory.

One or two review meetings are held each year at which grant holders or their research assistants describe the progress of their research to fellow cofunded grant holders, members of the Cofunding Panel and other senior representatives from CEGB and SERC. Every cofunded grant is reviewed in this way at least once.

In order to make effective use of the funds available, the Cofunding Panel has identified the following four priority areas for research, but good proposals in other areas of relevance to the CEGB would also be considered:

- Power electrical engineering
- Computational fluid dynamics
- Integrity of power plant materials
- Nondestructive testing and novel instrumentation.

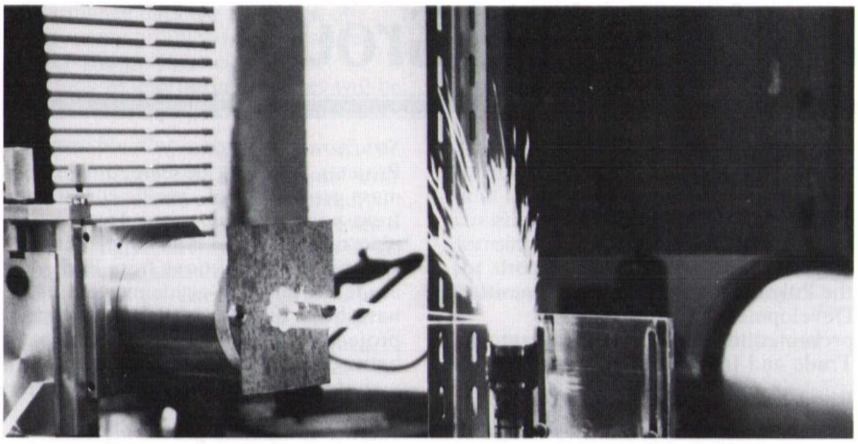
Power electrical engineering was chosen because of the long-term need to refurbish or replace the existing national grid and also to take advantage of the rapid advances in technology.

Computational fluid dynamics is at an exciting stage of development from an industrial point of view, especially because the new supercomputers are beginning to be able to deal with difficult three-dimensional problems and turbulence, offering industry a cheaper and quicker alternative to expensive experimentation in traditional areas such as turbine fluid mechanics and heat transfer.

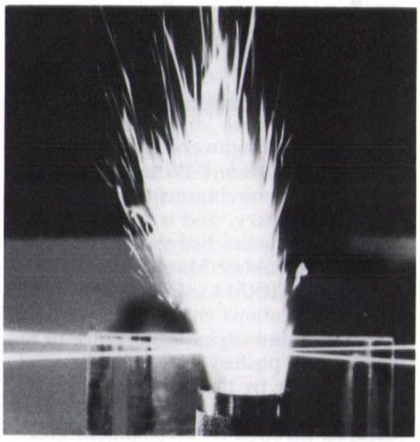
The integrity of power plant materials is central to the improvement of the efficiency and lifetime of power stations and is therefore an obvious candidate for inclusion.

Non-destructive testing techniques and novel instrumentation are also fairly obvious given the continual need for safe and reliable nuclear plant and for more sophisticated monitoring techniques required to meet demands for environmental control.

The current cofunded programme supports 14 grants with a total value of £600,000 in 11 different universities. The general view of the Cofunding Panel is that all the completed projects were generally successful in fulfilling their objectives and so it is difficult to single out specific examples. However, three of the first grants to complete illustrate the value of cofunding. Dr Nancy Nichols (Mathematics, Reading) had a grant to develop optimal control techniques for



Simultaneous measurement of the size and velocity of fuel particles by phase-Doppler anemometry in a swirl-stabilised flame. The transmitting optics of the anemometer lie to the left of the flame and the receiving optics module is at 30° to the forward scatter direction.



Close-up of flame with heterogeneous combustion showing intersecting laser beams, from a phase-Doppler anemometer, measuring droplet size and velocity simultaneously.

various tidal power generation schemes and as a result has provided the most realistic predictions of efficiency available. Dr Daryl Almond and Mr Harry Reiter (Materials Science, Bath) developed a novel non-destructive technique for using pulsed lasers to examine the bond between a plasma-sprayed coating and a steel substrate which is being applied in both nuclear and conventional power plant and also has commercial potential for other industries. Professor Jim Whitelaw and Dr Alex Taylor (Mechanical Engineering, Imperial College of Science and Technology) have recently been awarded a second grant to continue their research into the movement of coal particles in a turbulent fluid flow. This is part of a long-term commitment to combustion research by SERC and CEGB and is aimed at improving understanding of flame stability and burner design (see figures), which could have considerable economic benefits in the long-term.

Enquiries about the programme should be made to the Cofunding Officer:

Dr J G Andrews

Central Electricity Generating Board
Marchwood Engineering Laboratories
Marchwood
Southampton
SO4 4ZB

Metal defect tests on the HVEM

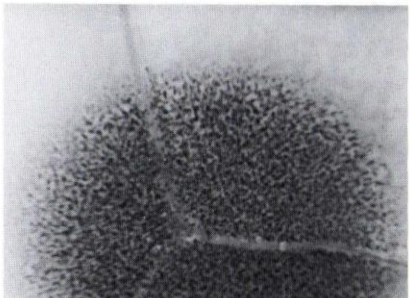
It has been known for many years that the tendency of impurities to gather at the boundaries of the grains in metal can cause devastating loss of strength and lack of resistance to corrosion. But it has only recently become clear that, in an environment of energetic electrons or neutrons, such as in a nuclear reactor, segregation can occur that has nothing to do with thermodynamic equilibrium, which up to now is where most work has been done.

It can now be shown that the impinging particles set up fluxes of lattice defects (vacancies and interstitials) to the grain boundaries. Such fluxes can drag impurities to the boundaries if there is an interaction term between the defect gradients and the flow of impurities. These effects are of fundamental interest because of the underlying defect interactions, and of considerable potential consequence for nuclear reactor design and operation.

Until recently, it has not been possible to see these effects: in reactor environments, they may take many years to develop. However, in the focused high-intensity beam of the high voltage electron microscope (HVEM), a segregation profile can be formed in a few minutes.

The figure shows radiation damage at the point where three grains meet in a Al - 4.5 atomic % Zn alloy. The damage (the black dots) is clearly suppressed at the boundaries because of the disappearance of defects there — the boundary acts as a sink for defects. And subsequent analysis by X-ray spectroscopy shows that zinc has been drawn to the boundary as a result of the irradiation. These experiments are rapid and convenient, and enable various combinations of metals to be examined, and the effects of temperature and dose to be rapidly assessed. They were performed on the AEI EM7 supported by the SERC Materials Committee at Birmingham University's Department of Metallurgy and Materials.

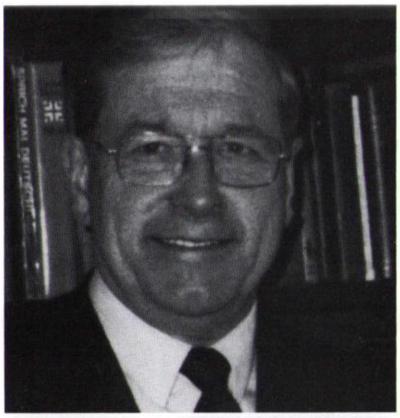
Although the radiation environment in an HVEM is different from that in a nuclear reactor, it is widely accepted that the qualitative understanding of radiation-induced impurity segregation gained from these experiments provides invaluable background knowledge for reactor design and operation.



Radiation damage at a triple point in Al - 4.5 $^{a}/_{o}$ Zn irradiated to 14 dpa at 14°C in an AEI EM7 HVEM. Zinc segregation profiles up to the grain boundary are subsequently monitored by STEM/EDX. (Photo: Birmingham University).

The Polymer Engineering Group

The Polymer Engineering Group was formed in October 1986 to promote research and development for the polymer industry, and is sponsored by the British Plastics Federation (BPF) and the British Rubber Manufacturers Association (BRMA). Close contact with both organisations enables programmes of strategic industrial importance to be defined and pushed forward. The work outlined here by the Group's Director, Dr John Baldwin, ranges from basic research through to development and exploitation, so that academic institutions and other centres such as Research Associations and Government Laboratories are often involved.



Dr John Baldwin, PEG Director

The Group undertakes for SERC's Process Engineering Committee much of the work previously done by the Polymer Engineering Directorate in stimulating and reviewing academic research, and in this respect reports to the Polymer Engineering Subcommittee. Development projects are also promoted through the Department of Trade and Industry.

Remit

The main elements of the PEG remit are:
- to formulate technical strategy with the polymer industry;
- to promote R&D programmes to meet the needs of industrial companies;
- to advise companies on technical skills, resources, and the main thrusts of technology at the polymer research centres;
- to monitor progress on selected academic projects for SERC;
- to encourage initiatives in education for the polymer industry.

Key target areas

Priorities for immediate work within the framework of the industrial R&D strategy have now been clearly defined, and new programmes have been started in some of the important areas. Strategic themes include structural composites in stressed applications, mass production of composite components, engineering design with polymers, improvements in product quality and consistency in engineering applications, polymer bonding, and education. Examples of work in progress are given below.

Structural composites

Projects are being developed for the mass production of specific components from polymer composites. Fast placement of fibres is an important issue. Technical contributions from both academic and non-academic centres have been brought into these industrial projects, which involve collaboration between fabricators, machinery manufacturers and materials suppliers.

Rubber compound processing

The main aim of this work is to develop and exploit technology for producing mixed rubber compounds of high consistent quality which meet the needs of downstream industries in terms of component properties and processing efficiency. A major project on the rheological behaviour of elastomers, which has been set up at Loughborough University with funding from SERC and from five industrial companies, provides the platform for this initiative.

Performance data for selection and design

Work commissioned at the National Physical Laboratory with industrial sponsorship to define standard methods for measuring and presenting data for specifying and selecting plastics materials has now been completed. This represents the essential first step in moving towards a common approach to engineering design. A programme is being prepared for promotion across industry and within Government to define improved design procedures and

Professor Mike Bevis and Dr Peter Allan, of Brunel University's Wolfson Centre for Materials Processing, examining thick sectioned polymer composite components produced by live feed moulding technology.

PEG-supported research in cooperation with industry has led to the development of complex composite ropes that are more durable than steel strands. Here, Professor Derek Hull is holding a partially crushed glass fibre-polyester resin tube that has been tested on his catapult crash rig at Cambridge University's Department of Materials Science and Metallurgy. (Photo: COI).

performance data for the range of components produced from plastics, rubber and polymer composites. Research at appropriate centres will be required to support the programme.

Polymer bonding

By consultation with industry and with the main research centres involved, broad R&D areas have been identified for bonding technology, which is of key importance to users of plastics, rubbers and composites. These areas include bond design and assessment, surface science, mass production techniques, and improved performance in the bonding of rubbers. The next task is to stimulate appropriate projects.

Education

Following the SERC announcement of eight more Integrated Graduate Development Schemes being set up, PEG has stimulated draft proposals from polytechnics and universities on polymer engineering/polymer technology (Manchester Polytechnic); packaging (Brunel and Loughborough Universities); and advanced materials (Surrey University).

The series of Advanced Summer Schools for University and Polytechnic Lecturers held at Manchester Polytechnic will be continued in 1988 with the first of a series based on market sectors. This year the theme will be *Polymers in the automotive and aerospace industries*.

A contact point for industrialists and researchers

PEG is based in the BPF offices, at the address below, and is ready to advise or assist any UK company or research centre. A Group member often operates as a broker, with full confidentiality when required, assessing where research expertise in the UK centres may directly benefit an individual company, and assisting in definition of a joint technical programme. The team comprises:

Dr John Baldwin, PEG Director (composites projects, Integrated Graduate Development, academic review in the North, strategic linkage to BPF);
Dr Gerry Dodd (bonding projects, developing technical information sources);
Mr Peter Fisher (rubber projects, strategic linkage to BRMA);
Mr Fred Parmenter (academic review in the South);
Dr John Lockett (engineering design projects).

Researchers and industrialists are invited to contact a PEG member on a specific research project, or to contribute to the R and D strategy.

Dr John Baldwin
Polymer Engineering Group
5 Belgrave Square, London SW1 8PH
Telephone 01-235 7286

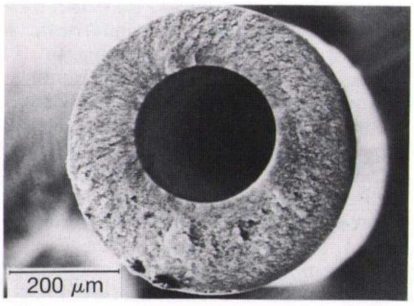
Support for research on synthetic membranes

The study of synthetic membranes and their use in bringing about molecular separations is an interdisciplinary topic cutting across the fields of at least five subject committees of the Science and Engineering Boards. A coordinated approach to support research on membranes was initiated at the end of 1984 when the Chemistry, Process Engineering and Biotechnology Management Committees asked Professor Patrick Meares of Exeter University to review the area. His subsequent report* was widely circulated in the autumn of 1985 after the Biological Sciences, Chemistry, Materials, Process Engineering and Biotechnology Committees had supported its main recommendations.

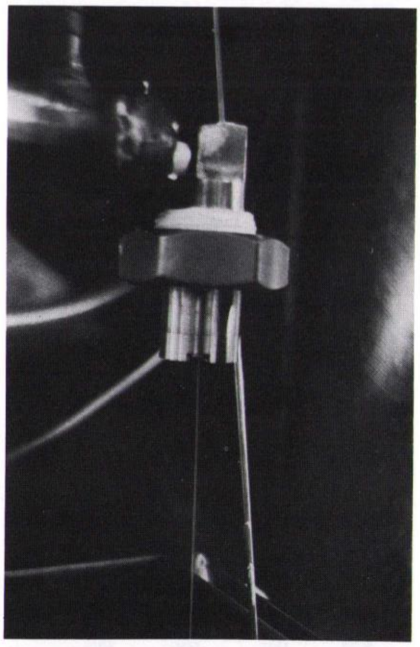
To implement these recommendations, Professor Meares was appointed Membranes Coordinator and a steering group was set up with one representative of each of the committees named above. This became the Membranes Working Party, which held its first meeting in October 1985. The Working Party had no budget and its main function was to encourage applications for research grants on synthetic membranes, to advise would-be applicants and to make comments and recommendations on grant applications to the subject committees that received them.

The Working Party reviewed some 60 grant applications and re-applications; of these, 18 qualified for funding to a total value of £1.02 million over periods up to three years. A progressive improvement was evident in quality and success rate of the proposals as the initiative proceeded. Currently, five projects are receiving support on gas separation membranes, four on protein filtration, three each on liquid membranes and pervaporation and three on various topics.

In order to meet the growing importance of improved separation procedures in industrial operations, a wider initiative was announced by SERC in November 1987. To support this initiative, the Engineering Board in conjunction with the Biotechnology Directorate has set up a Separation Processes Programme (see *SERC Bulletin* Volume 3 No 10 Spring 1987), which has subsumed the functions of the Membranes Working Party; Professor Meares has been retained as Coordinator for membranes research under the Programme Manager, Professor Jack Richardson FEng. Membrane research continues to be an important concern of the new programme which, because of the momentum already developed, has so far tended to have its considerations dominated by membrane research proposals.



An electron micrograph of the porous structure of the wall of a spun polyether-sulphone fibre. (Photo: Leeds University).



Spinning a porous hollow fibre membrane for use in gas separation. The freshly spun fibre descends through air from the spinneret into the coagulant bath. (Photo: Leeds University)

**Synthetic membranes and their applications.* SERC 1985. Copies available from the Biotechnology Directorate, SERC, Swindon.

Lasers for scientific research

The Laser Support Facility at Rutherford Appleton Laboratory is three years old and now has six lasers on loan to universities and experiments running in four laboratories at RAL. Any member of academic staff can apply for laser loans or for time on lasers at RAL, free of charge, for research in chemistry, biology or physics. Research workers in 30 institutions have published more than 60 papers since 1985 on topics ranging from enzyme catalysis to the ionisation of molecules on a femtosecond timescale. The facilities, which may also be hired by researchers in other fields or by industry (BP, Rolls-Royce and STC are among the customers) are described here by Bill Toner of RAL.

The Laser Support Facility (LSF) staff of five scientists are supported by Central Laser Facility technicians and by a small laser development group. Such a small group cannot cover all of laser-based science and so the initial effort has been concentrated on providing an extensive suite of pulsed tunable dye lasers with excimer or YAG pumps. These lasers are much in demand and this choice also makes best use of the back-up expertise of other staff at RAL. The general aim is to provide equipment which is too expensive for most groups to acquire without a major grant, or too complex for any but specialist laser groups to maintain, such as the picosecond system based at RAL.

The lasers at RAL are scheduled with experimental runs of, say, one to three weeks, in much the same way as an accelerator.The loan pool had no obvious precedent in the UK although a successful model was provided by the National Science Foundation's San Francisco Laser Center. Loans of up to three months at a time are made to users anywhere in the UK: Edinburgh, Essex, Sussex and Southampton Universities have all had loans. Staff inspect the site — the 'small' lasers of the LSF weigh up to half a ton — and arrange for the laser to be delivered and for maintenance. At the end of the period, the laser is moved to the next user. The scheme was not without its teething troubles. For example, the cold weather of 1986 revealed that, after draining in the recommended way, one of the lasers still contained quite enough coolant to damage the laser when frozen. But on the whole the lasers have turned out to be much less delicate than had been feared.

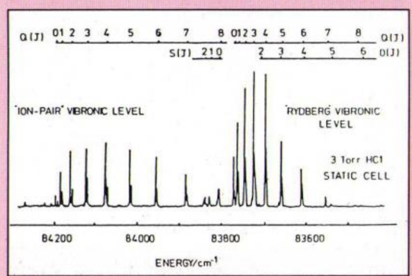


Figure 1: Multiphoton ionisation spectrum of electronically excited HCl.

The main purpose of the LSF is to enable more good science to be done. The few examples given below have been chosen to give the flavour of the work and to illustrate the benefits of the cross-disciplinary collaborations which grow naturally from the development of common facilities by a community of users.

Biology

The biological applications of LSF lasers have great diversity. At University College London, a loan pool laser is used to saturate the photosynthesis in large enough samples of plant material for later analysis by electron paramagnetic resonance. Research at King's College, London, again using a loan pool laser, has shown that one-dimensional 'facilitated diffusion' of proteins along DNA chains can be observed and measured. In this work a chopped beam from an ion laser was focused to an intensity high enough to induce localised bleaching and fluorescence produced by a probe beam was used to measure the recovery time of the bleached region, from which the diffusion rate of the protein (histone H1) could be deduced. At RAL, good progress is being made in an ambitious study of *in vivo* DNA damage repair mechanisms by a Birmingham-Sussex-Medical Research Council collaboration using a radioactively labelled 'caged' repair inhibitor whose synthesis alone is a formidable challenge. Live mammalian cells permeated with this material in its inert, caged form are irradiated with a pulse of ultraviolet light of 248 nanometre wavelength which damages the cellular DNA but has no effect on the caged compound. At a later time, a pulse of light of 351 nm wavelength breaks the cage to activate the repair inhibitor, and a subsequent radio-assay measures the uptake of the inhibitor and thus the amount of unrepaired damage. Other biology experiments at RAL include picosecond measurements of photosynthesis (Lancashire Polytechnic-RAL), picosecond fluorescence measurements of genetically engineered proteins (Bristol University-RAL) and the development of scanning X-ray microscopy techiques using X-rays produced by high-repetition rate lasers focused to micron-sized spots (King's College-RAL), a programme which originated in experiments on the high power VULCAN and SPRITE lasers.

Chemistry

Research in chemistry accounts for more than two thirds of LSF use but there is space here for only one or two examples. The gas phase is represented by the work of a group from Reading University who have used a multipass absorption cell to study the kinetics of reactions of the dimethyl silylene radical with unsaturated hydrocarbons and related species. An excimer laser generates the radical by photolysis of pentamethyl di-silane and an ion laser is used to probe the radical concentration. Reaction rates were found to depend progressively on the availability of the π electron from the donor to fill the empty p orbital of the radical. The results have given new insights into addition reactions. Interesting results on the structure of electronically excited states of HCl have been obtained by chemists at Edinburgh, using a loan laser. 'Ion-pair' and 'Rydberg' states are strongly mixed. Figure 1 is a multiphoton ionisation spectrum from this work. Gas phase reactions have also been studied in Birmingham, Heriot-Watt, Manchester, Nottingham and Southampton Universities. Work on solid state chemisty is exemplified by a classic study made at Oxford University of two-photon absorption in single crystals of $Cs_2UO_2Cl_4$ cooled to 4.2 K. The data clearly reveal the electronic origin transitions of 13 of the 14 excited states below 33,000 cm^{-1} and polarisation data enable a complete symmetry analysis to be made. The clarity of the spectrum is illustrated in figure 2. Chemists from Loughborough, Nottingham and East Anglia Universities and Lancashire Polytechnic

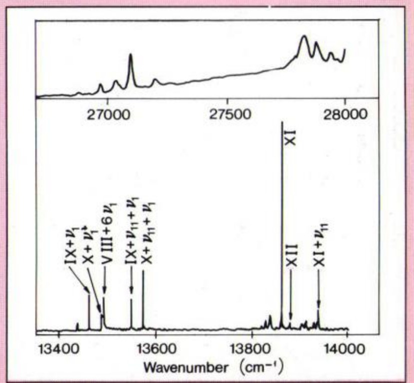


Figure 2: Portion of absorption spectrum of $Cs_2UO_2Cl_4$. Upper trace: one-photon absorption. Lower trace: two-photon spectrum with line identification.

are also active users of the picosecond laser. An example of a picosecond transient in diffuse reflectance from a polycrystalline sample obtained by the Loughborough group is shown in figure 3.

The spread of advanced techniques through the community is well illustrated by the Raman scattering programme at RAL where methods developed by York University and the Royal Institution for an extensive study of anthraquinones were used by Birmingham and York for work on enzyme catalysis, by Queen's University of Belfast for measurement on organometallic complexes, and by BP for the analysis of hydrocarbon mixtures. Results have included the first observation of an acyl enzyme intermediate in naturally occurring enzyme catalysis and the first examples of Resonance Raman Scattering from metal-ligand-charge-transfer states of copper complexes and from transients in the photolysis of the Fischer complex. Picosecond Raman techniques are now being developed.

Physics

Physicists also use LSF lasers. Loans have been made to Strathclyde University for work on phase conjugation, to Essex for measurements of phonon spectra and to Imperial College of Science and Technology for measurements of line shapes in dense plasmas. The picosecond facilities at RAL arouse the greatest interest. The most elaborate experiment was to transmit a train of pulses at 746 nm through a 70-metre optical fibre to another building where a selected pulse was amplified, converted to 248.6 nm and injected into the SPRITE laser chain for amplification to an energy exceeding one Joule. SPRITE now has its own picosecond source and has produced a world record output of 2.5 Joules in 3.5 picoseconds. The simplest experiment from the laser point of view was the excitation of luminescence in amorphous semiconductors mounted in a helium cryostat brought by a group from Exeter University. The success of their measurements of luminescence decay helped make the case for a picosecond system at Exeter.

From a physics point of view, the most exciting results have come from a Reading-RAL collaboration studying molecular dissociation. For this work, the pulse was shortened to 600 femtoseconds and intensities in the focal spot reached 3×10^{15}Wcm^{-2} generating electric field strengths which were a significant fraction of the binding fields of the atoms. Figure 4 shows the chamber in which the beam was focused and figure 5 is an ion time-of-flight spectrum from the dissociation of nitrogen. Dissociative ionisation was found to proceed sequentially from singly to doubly, triply and quadruply ionised molecules and then in a two-electron jump to the sextuply charged molecule. The time taken for the whole process is estimated at less than 30 femtoseconds by considering the velocity with which highly charged ions separate under coulomb repulsion. This work is now being extended to higher intensities using excimer lasers to amplify the sub-picosecond pulses.

The LSF user-base continues to expand in numbers and breadth of subject and staff look forward to an equally stimulating programme in the next three years.

W T Toner
Rutherford Appleton Laboratory

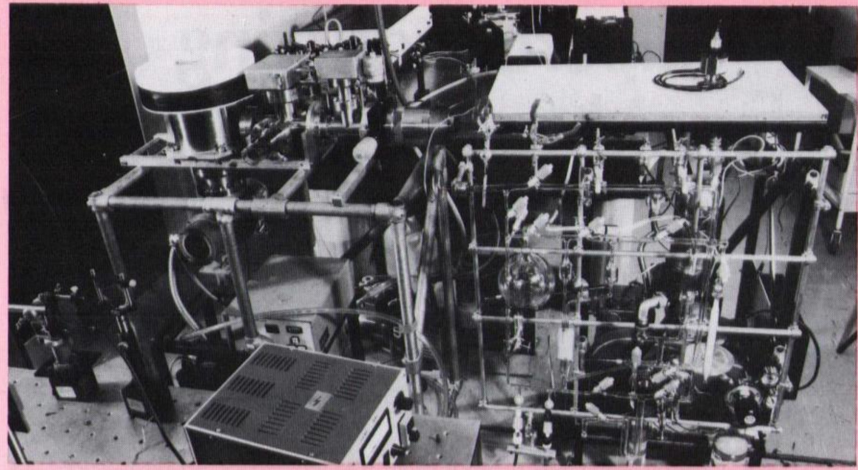


Figure 4: Picosecond laser apparatus for high intensity dissociative ionisation experiment.

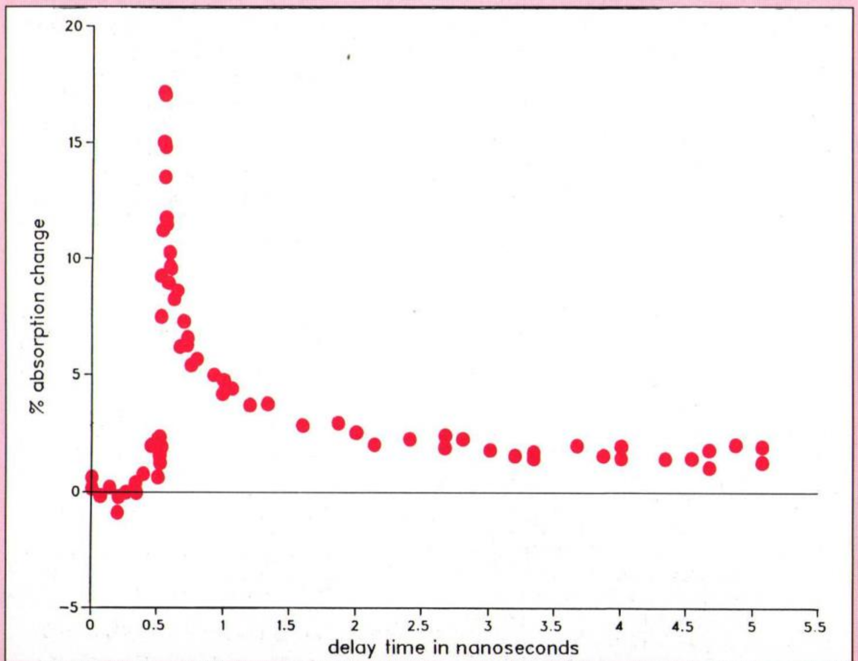


Figure 3: Diffuse reflectance transient.

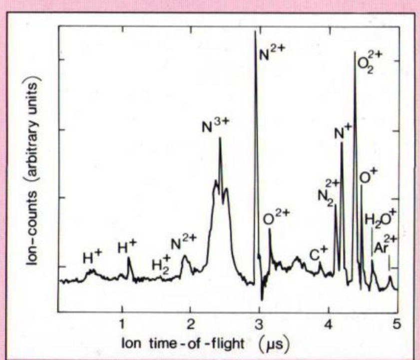
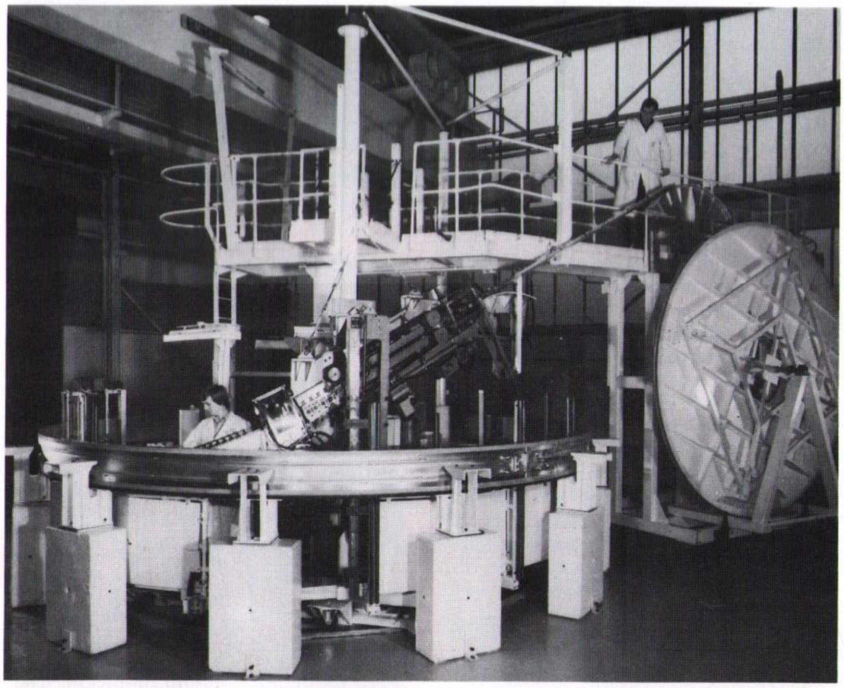
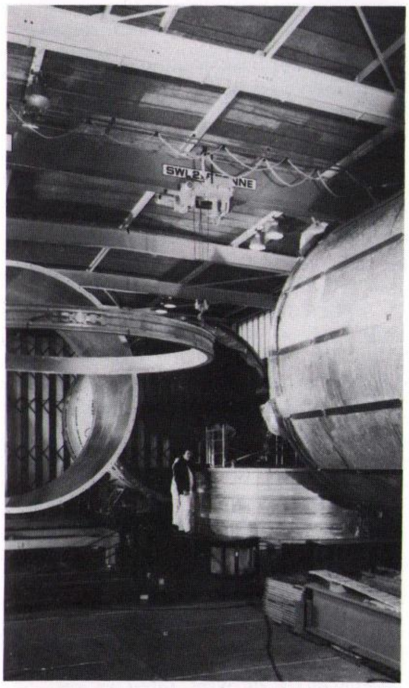


Figure 5: Ion time-of-flight spectrum at a laser intensity of 3 × 10^{15}Wcm. Target gas was N_2,O_2 mixture.

The superconducting solenoid for DELPHI

As reported in *SERC Bulletin* Volume 3 No 10, Spring 1988, the world's largest superconducting solenoid set out from the Rutherford Appleton Laboratory in October 1987 on its way to CERN in Geneva. The solenoid, described here by Peter Clee of RAL, is required to provide a field of 1.2 Tesla, over a volume of 145 m^3 for the DELPHI collider experiment, which will be operated at the large electron positron (LEP) accelerator at CERN. The solenoid was designed and constructed by RAL under an agreement with CERN which was signed in 1984.





Above: The coil winding machine with the conductor being fed into the coil cylinder, which remains static while the conductor reel and feed rotates around it.

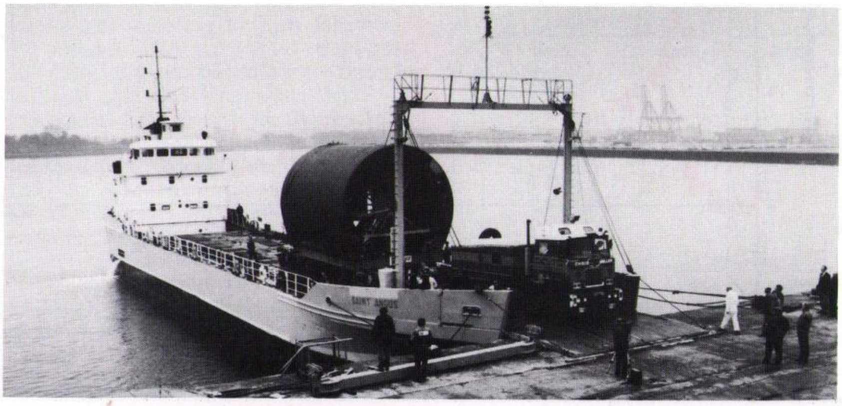
Left: The inner and outer shells of the vacuum vessel with the radiation shield panels attached and the assembly of the coil sections in progress.

Below: Solenoid loaded on the ship at Southampton.

In producing a solenoid of this size (6.2 metres outside diameter, 5.2 metres inside diameter, 6.8 metres long, weighing 88 tonnes and a stored energy of 100 MJ), special consideration was given to reliability and safe operation. To meet the physics requirements, the solenoid construction material was limited to a radial thickness equivalent to four radiation lengths (330 mm of alumunium, for example) and the magnetic field homogeneity was specified as 5 gauss metres out to a radius of 1.25 metres and 25 gauss metres out to a radius of 2.5 metres over any detector module length. The solenoid was also required to support the 150 tonne weight of the internal detectors without distorting more than 1 mm.

The design concept chosen to meet this specification involved a novel technique (developed at RAL) of winding the 20 km of conductor on the inside of a cylinder, rather than the usual practice of winding on the outside. This allows the cylinder, rather than the conductor, to hold the magnetic bursting pressure of 6 atmospheres. This pressure also ensures good thermal contact between the conductor and the cylinder. Liquid helium is pumped through tubes attached to the outer surface of the cylinder to cool the conductor to 4.5 K where it becomes superconducting.

Winding the coil involved forcing the conductor which was first double half-lapped with glass tape impregnated with



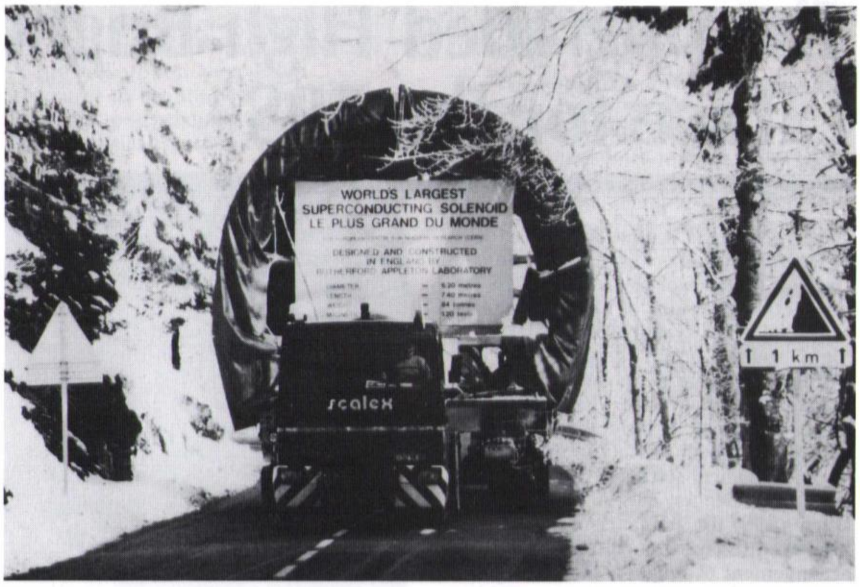
epoxy resin, down a ramp on to the inside surface of the cylinder. After winding, the conductor was compacted and pressed on to the cylinder wall and the resin was cured by heating in an oven at 120°C. The complete coil was built in four 1.5 metre long sections, single layer-wound, plus two 0.35 metre long end-sections that were double layer-wound to meet the field uniformity requirement when operated with the 2500 tonne iron yoke. The magnet design was carried out using two programs developed at RAL: an axisymmetric code PE2D and a three-dimensional code TOSCA. In both codes, a facility to represent the laminated iron yoke as solid with anisotropic properties was implemented, which greatly simplified the modelling of the structure. The six sections were bolted together and the conductors were joined by edge-welding over a length of 18 metres; these joints had a resistance of up to 10^{-9}ohms.

The conductor consists of 17 wires of 0.7 mm diameter twisted to form a cable, with each wire having 300 niobium-titanium superconducting filaments 25 microns in diameter, embedded in a matrix of copper. The cable is clad in high-purity alumunium with an overall cross-section of 24 mm × 4.5 mm. The aluminium protects the superconductor in the case of a fault condition where the superconductor becomes resistive. If such a fault occurs, it is detected by sensitive measurement of voltage appearing across the coil. This in turn provides a signal to open fast-operating breakers. The breakers disconnect the coil from the power supply and 95% of the stored energy is dumped in a resistor which is externally connected in series with the coil. The conductor is designed with a safety factor of two on the required operating current of 5 kA.

The assembled coil is suspended on low conducting rods inside a cryostat which thermally isolates it from the external room temperature environment. The cryostat is built up with an external stainless steel vacuum vessel, an 80 K gas-cooled radiation shield and interspaced blankets made from multiple layers of aluminised mylar. The inner volume of the vacuum vessel is evacuated initially by a large rootes pump and then two diffusion pumps to a pressure of 2×10^{-6}mm Hg.

The solenoid is fully instrumented and controlled by a computer which is programmed to carry out all the operating and protection functions automatically.

Before leaving RAL, the solenoid was vacuum-tested, checked for leaks and cooled to 80 K. A special trailer was provided by CERN to transport the solenoid from RAL to CERN. It had 20 pairs of wheels which were all steerable



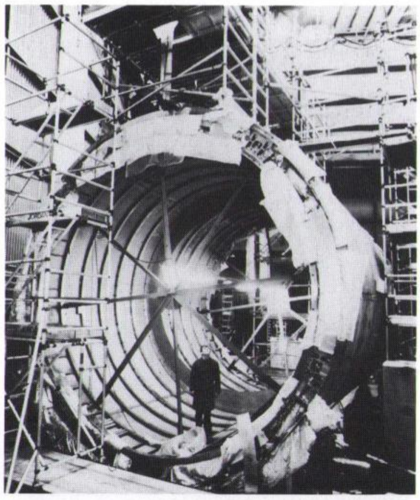
Traversing the Col de la Faucille in the Jura mountains.

and could be raised or lowered hydraulically. The solenoid remained attached to the trailer throughout the journey.

Transporting a load of this size and weight would present some difficulty under normal conditions; in planning the operation, no-one could foresee that the trailer would leave RAL the day the worst hurricane for 300 years hit the South of England. The route to Southampton was scheduled to take four days but in practice it took 14 days, due mainly to the Electricity Board and British Telecom being involved in repairing lines damaged by the hurricane and not having linesmen available to lift or remove cables in the way of the solenoid. At Southampton, the solenoid was loaded on to a ship and on 1 November it sailed to Rotterdam. The following evening the solenoid was transferred to a Rhine barge by a large floating crane and on 6 November it arrived at Strasbourg.

At this point more problems surfaced. In the first instance a contractor building a new bridge 40 km south of Strasbourg had decided, without permission, to block the road. The firm was instructed to build a bypass and this operation took a week. On the evening before the load was due to move off, the trailer steersman was knocked down by a car mounting the pavement and his leg was broken in three places. A replacement steersman was found and the load moved off through France. By the end of November it arrived at the pass over the Jura mountains in time for the first major snowfall of the winter, followed by temperatures of −15°C. On 4 December the solenoid reached its destination and is now installed in a large building in the west area. Here it is being cooled to 4.5 K by a large refrigerator and tested to up to 30% of the operating current. The solenoid will not be installed in the iron yoke for this test, and so the operating current is limited by the change in force pattern within the coil and the large fringe field affecting the operation of supporting equipment. The test will however enable all the equipment to be commissioned before installing the solenoid during the summer of 1988 in experimental pit No 8, which is located 100 metres below ground near Geneva airport.

P T M Clee
Rutherford Appleton Laboratory



The solenoid being installed for testing at CERN. (Photo: CERN).

The upgraded High Brightness Lattice for the SRS

The Synchrotron Radiation Source (SRS) at Daresbury Laboratory is a circular electron accelerator dedicated to the production of beams of electromagnetic radiation. This synchrotron radiation 'light' spans a broad range of wavelengths from penetrating X-rays, through the ultraviolet, visible and infrared regions of the spectrum. It can be used in a wide variety of experiments in the biological sciences, chemistry and materials sciences, as well as physics. During 1987 the brilliance of the SRS was improved ten-fold by changing the arrangement of magnets in the ring to make a High Brightness Lattice (HBL) (see *SERC Bulletin* Volume 3 No 10, Spring 1988). In this article, Margaret Martin of Daresbury details the science of the improved facility.

Newer storage ring designs have concentrated on producing beams with small size and divergence to increase the brilliance of the synchrotron radiation. In the HBL, smaller dimensions of the electron beam circulating in the accelerator have been achieved by adding new focusing magnets (see figure 1). Reducing the electron beam dimensions in turn enhances the brilliance of the emitted synchrotron radiation beams. The overall flux of emitted light remains the same, but comes from a smaller source, so that more of the light can actually be focused on to the experimental sample.

Installing the HBL was a major engineering modification to the machine. This work was completed to schedule and to budget and, after a period of commissioning, many user groups from universities, polytechnics, the Medical Research Council, industry and overseas research institutions were back at Daresbury carrying out experiments by the late summer of 1987.

Frog muscle experiment

A small-angle X-ray scattering experiment on a sample of frog's leg muscle was the first to demonstrate the improvement in resolution made possible by the increased brilliance resulting from the HBL upgrade. Figure 2 shows a comparison between diffraction results obtained before and after the lattice conversion. In the latest results, the diffraction spots are much better defined and there is better angular resolution close to the centre of the pattern. The diffraction technique allows molecular biologists to investigate the structural arrangements of biologically important molecules such as proteins and to determine how that structure is related to biological function. In the case of muscle, the diffraction patterns show how the fibrous muscle proteins are assembled and how this arrangement changes when the muscle contracts. The improved angular resolution paradoxically enables larger structural assemblies to be detected. This requires measurements at very small scattering angles, close to the direction of the X-ray beam. Such long-range structural order seems to be crucial to the molecular mechanism of muscle contraction.

Another X-ray technique, EXAFS (Extended X-ray Absorption Fine Structure), is used to investigate very short-range structure in a wide variety of materials including metalloproteins, glasses and the recently discovered high-temperature superconductors. One such material, $Ba_2YCu_3O_7$, has a critical temperature (T_c) above that of liquid nitrogen. EXAFS measurements at the barium L_3-edge, the yttrium K-edge and the copper K-edge have been made both at room temperature and at liquid nitrogen temperature, to examine the local environments of the three cations. Such a range of measurements is possible using the ability of the SRS to tune wavelengths to scan across the different X-ray absorption edges of the three cations. Analysis of the results (figure 3) has yielded the interatomic distances, which provide direct evidence for unequal spacing of the cation planes, indicate the absence of oxygen atoms in the yttrium plane and lend support to the existence of puckered copper-oxygen-copper layers in the structure. There was no structural change associated with the superconductivity transition between room temperature and 77 K, but the Debye-Waller factors of the three cations, which are an indication of the strength and rigidity of the structural bonds, showed anomalous temperature dependence.

Industrial research

Many of the techniques available using the SRS are being exploited for industrial as well as academic research. Grazing incidence X-ray diffraction studies of the surfaces of silicon wafers have revealed near-surface defects, which are associated with problems in the fabrication of semiconductor devices. This work was part of an Alvey cooperation between GEC, British Telecom, Plessey and Durham University. High-angle X-ray diffraction measurements have been used by Keele

Table 1. HBL/SRS parameters for 1Å, 2 GeV

	Bending magnet (1.2 T) centre tangent	**Wiggler** (5 T)
Flux [photons/sec/100 mA/mrad horiz./ 0.1% bandwidth]	2.94×10^{11}	3.37×10^{12}
Brightness [flux/mrad vertical]	1.21×10^{12}	8.29×10^{12}
Brilliance [flux/mrad vertical/mm^2]	1.46×10^{12}	9.7×10^{12}
Pulse width fwhm (psec)	120	
Interpulse separation (nsec)	2, or 320 in single bunch mode	

Notes

1. *Brightness is the photon flux taking into account the electron beam divergence* and *the radiation (1 Å) opening angle.*

2. *Brilliance is the brightness taking into account the electron beam source size.*

3. *In the HBL/SRS, the brightness is only significantly enhanced at the short wavelengths. It is the source* brilliance *which has been markedly improved in the HBL by reducing the electron beam size.*

University and ICI to study crystallisation occurring during the drawing process in the manufacture of polymer fibres. The brilliance of the HBL/SRS allows these measurements to be made in real time, so that the time course of the process can be followed.

An industrial consortium comprising ICI, Shell and BP have applied the techniques of EXAFS and XANES (X-ray Absorption Near-Edge Structure) to the study of catalysts. Chemical, petrochemical and pharmaceutical synthesis rely extensively on the action of catalysts. Short-range structure may prove to be fundamental to catalytic function.

The tremendous improvements in resolution made possible by the availability of high brilliance synchrotron radiation allow accurate structures to be obtained from very small protein crystals using X-ray diffraction techniques. Improved angular resolution is important for small angle X-ray scattering experiments on larger structural assemblies such as viruses and cytoskeletal proteins. In some cases, faster exposure times allow dynamic processes to be studied. Reduced beam dimensions also benefit research in X-ray microscopy, microprobe trace element analysis and EXAFS of small crystals. A wide range of experiments will benefit from the increased source brightness, ensuring that the SRS remains a leading international facility well into the next decade.

Dr M M Martin
Daresbury Laboratory

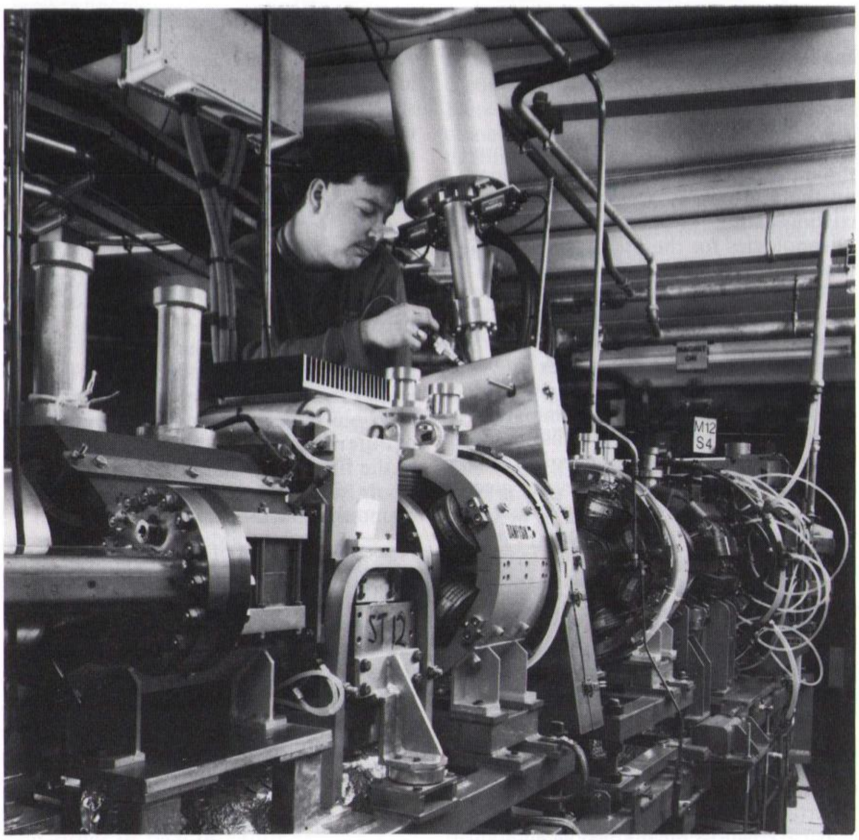


Figure 1: One of the 16 new straight sections of the modified SRS storage ring.

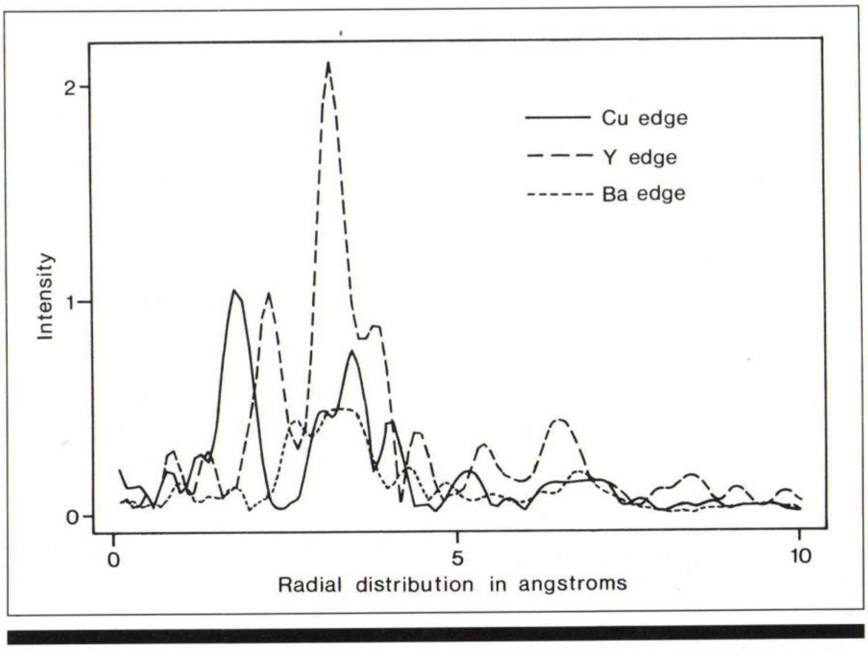


Figure 3: Fourier transforms of the EXAFS of the high T_c superconductor, $YBa_2Cu_3O_7$, at the three cation absorption edges.

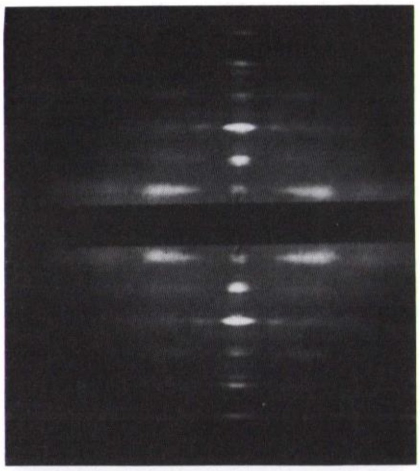
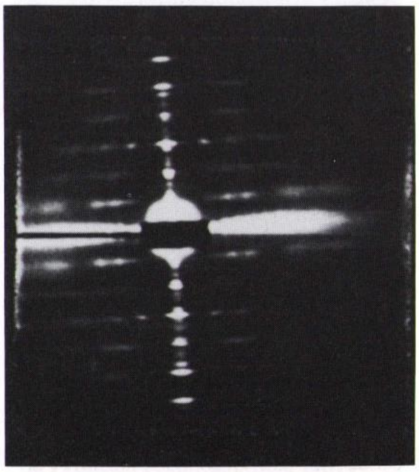


Figure 2: Diffraction pattern from muscle obtained using the SRS before (above) and after (below) the HBL modification.



The Oxford Radiocarbon Accelerator Unit

The Oxford University Radiocarbon Accelerator Unit was set up in 1979 by the Research Laboratory for Archaeology and is largely funded through special research grants from SERC. Its aim is to develop the new technique of accelerator mass spectrometry (AMS), with which the Research Laboratory for Archaeology at Oxford was already involved, and to apply it to radiocarbon dating, especially for the benefit of research in science-based archaeology. Worldwide, some 20 to 30 accelerator laboratories are engaged in AMS research; a handful of these are purpose-built facilities, dedicated to the measurement of extremely rare long-lived radionuclides. Robert Hedges, Director of the Oxford Radiocarbon Accelerator Unit, discusses the technique and its applications.

Radiocarbon dating has until now depended upon detecting carbon-14 from its radioactive disintegration (beta counting). With a half-life of 5730 years, large samples are required (about 1 gram of carbon) in order to accumulate enough detected events in a reasonable time. However, when detecting carbon-14 mass spectrometrically, the sample size is determined by the efficiency of the system, and in practice can be more than a thousand times smaller than that required for the radiometric method. Such small samples allow a much better choice of material for dating, indeed making dating possible in many cases where before samples were either too small to provide sufficient material, or too precious to be destroyed.

Since an enormous radiocarbon database already exists, the foundations of dating are not likely to be overturned; but there are many areas where the existing dating framework is shaky (chronologies for the pre-literate Middle East, for example); controversial (like the entry of early Man into the Americas); sketchy through lack of suitable material (such as open Palaeolithic and Mesolithic sites in Europe); or confused (for example, by measurements made on contaminated material). In each of these situations, dating by AMS has already proved to be highly beneficial and examples are given later. But such work is only possible when based on a fully developed technology.

The technique of accelerator mass spectrometry

AMS is a technique developed over the last ten years in which a tandem electrostatic accelerator is coupled to a mass spectrometric system so that isotopes at an ultra-trace level can be measured. The original and most important application has been to measure cosmogenically produced radionuclides, such as beryllium-10, carbon-14, aluminium-26 or chlorine-36, since these have a natural abundance, relative to their common isotope, of 10^{-12} or less.

Any isotope is defined by its mass, M, and atomic number, Z. Mass spectrometry can, in principle, detect ions of a particular mass, but in practice the abundance of molecules or atoms with almost identical masses makes detection at levels below about 10^{-9} extremely difficult. Accelerating the ion beam to energies more than 1 MeV/AMU enables multiply-charged ions to be measured, eliminating molecules, and permits identification of the mass-selected particles through nuclear interactions which depend on Z. The main function of the system, then, is to filter out molecular ions and atomic ions of different mass, so that the particle flux to the final detector is reduced to a level where single particle events can be counted, analysed, and identified.

A second function of the accelerator is to provide high beam transmission. This is essential in order to obtain realistic count rates from ultra-trace elements. An equally important consideration is the generation of the negative ion beam, usually by a caesium sputter source. The characteristics of ion beams (efficiency of production, for instance) depend strongly on the particular ion in question.

Most stable isotopes tend to occur naturally at greater abundance than is suitable for AMS, so that most applications have been to measure long-lived radionuclides; shorter-lived nuclides are more easily measured through their radioactive decay. The majority of applications of AMS have been on the lighter nuclides (with mass of less than 60), although, for example, ^{129}I and ^{205}Pb are both studied. The main interest in the cosmogenic nuclides lies in their acting as tracers in the natural environment, in the information they provide about cosmic ray and other cosmogenic processes, and in their applications for dating.

Some application to stable isotopes has also been made. For example, the relative abundance of osmium isotopes acts as a tracer for terrestrial versus cosmic origins in sediments. There is also interest in developing the technique for the general measurement of trace elements in the 10^{-9} to 10^{-12} range.

Research at the Oxford Unit

The Unit designed and built its own AMS system, based on a 2 MV Tandetron (see figure 1). The ability to detect atoms down to the 10^{-16} level has required advances in particle

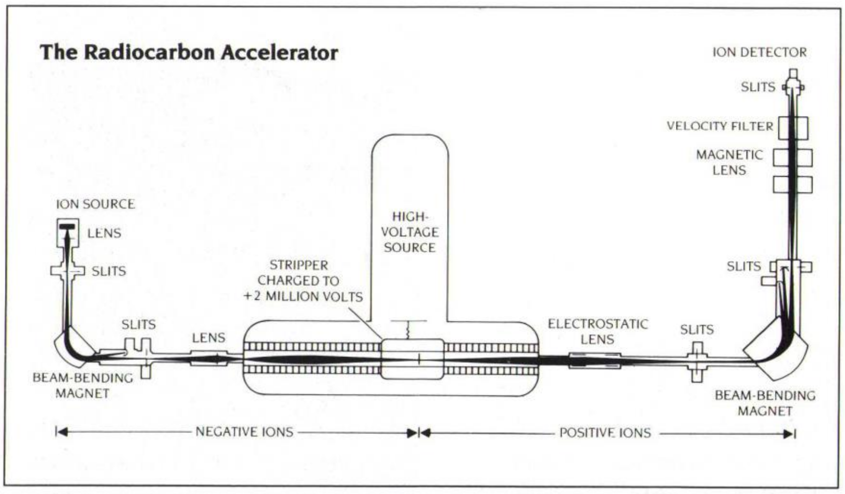


Figure 1: Configuration of the Accelerator Mass Spectrometer system at Oxford.

identification, and above all in ion source design. In addition, ion source research has successfully enabled samples in the form of CO_2 to be directly measured, and will continue to be important in the future, in for example, the development of microprobe facilities. Another spur to research is the rather high measurement accuracy (better than 1%) in the isotope ratio required for archaeological dating; this has necessitated both understanding and control of the ion beam optics to a high order. Much of the purely scientific research of the Unit has been towards the chemical fate of organic materials during burial, so that only those carbon atoms constituting the sample may be extracted for dating.

Range of expertise

The expertise of the Unit extends from the strategic choice of archaeological dating, through the tactical selection of context and sample, chemical identification, extraction and purification of appropriate material, to the measurement by AMS, and the interpretation and publication of the result. We have produced more than 1200 radiocarbon dates in the last three or four years, of which 90% are for research applied to archaeology. More than half of these dates are now published in a series of date-lists in the journal *Archaeometry*. We are now also actively studying the feasibility of applying the Oxford AMS system to wider applications.

The core of the work of the Unit has been either its own in-house dating programmes, or programmes of research undertaken in collaboration with archaeologists and scientists with SERC support through the Science-based Archaeology Committee. Future work, for which the Unit is increasing its dating capacity, is planned to include a wider spectrum of archaeological research, with additional funding from external sources.

Although the dating programmes are diverse (including samples from 57 different countries, some 20 different types of material, and all archaeological periods over the last 45,000 years), their value depends greatly upon their overall coherency. To promote this, the Unit has given priority to certain themes as being of particular interest. These include:

- Studies of contextual and stratigraphic problems;
- Upper Palaeolithic cave sequences;
- Late Palaeolithic open sites;
- Development of agriculture and domestication;
- Early Man in the Americas;
- Mesolithic and Neolithic skeletal remains (especially in Britain).

Some highlights of dating by the Oxford Unit

A good example of a precious sample is illustrated in figure 2. This is a parchment Mappa Mundi — a mediaeval map of the world — discovered as part of a binding for an Elizabethan manuscript. A fragment was dated and calibrated to 1020-1270 AD, which showed it was not a copy and suggested production during Henry III's reign. Since the King had his chamber at Westminster Palace decorated with a Mappa Mundi in 1230-1240 AD, the parchment is highly likely to be a copy of this, and a prototype for the famous (and later) Mappa Mundi in Hereford Cathedral.

Many art objects of the last 2000 years have been similarly dated in order to prove (or disprove) their authenticity. The Unit has provided this commercial service for artefacts as diverse as Chinese silk brocades and mediaeval ivory carvings.

The Oxford Unit is one of three laboratories chosen by the Archbishop of Turin to make radiocarbon dates on samples from the Shroud of Turin. If it is a mediaeval forgery, dating a square centimeter of cloth would settle the controversy.

Archaeological excavations often disclose objects of unique importance. For example, hairs from the moustache and undigested remains of Lindow Man's last meal have been dated. Artefacts have included the earliest string in the world (10,000 years old, from Guitarrero Cave in Peru), a drinking cup made from birch bark (Mesolithic, 9000 years old, from Germany), and a remnant of resin used to glue a flint arrowhead to its shaft (Upper Palaeolithic, Belgium).

Most of the dating work of the Unit, however, takes place in the wider context of other archaeological dates and sites. One example is the dating of a series of human skeletons found, dismembered, during the excavation of the Neolithic longbarrow at Hazelton, Gloucestershire. The period of use of such monuments is not known, and dating showed that two centuries probably sufficed for the building, use, and abandonment of the tomb. On a broader scale, the Unit has studied the origin of agriculture and animal husbandry in the Middle East by dating wild and domesticated forms of grain (figure 3), as well as gazelle and sheep bones. Several sites have been studied, with a particular focus on Abu Hureyra (Syria) and, by dating such specific material, a much clearer picture is emerging of the start of the 'Neolithic Revolution'. On a broader scale yet, a start has been made on dating the Palaeolithic levels in the 'classic' French cave sites, going back more than 40,000 years, since previous radiocarbon chronologies have suffered greatly from dating contaminated material. This should lead eventually to dating the transition from Neanderthal to Modern Man, throwing light from the twentieth century on one of the major turning points in Man's history.

Dr R E M Hedges

Oxford Radiocarbon Accelerator Unit

Figure 2: Part of a Mediaeval Mappa Mundi (Map of the World) found as a parchment binding, and dated by the Oxford laboratory.

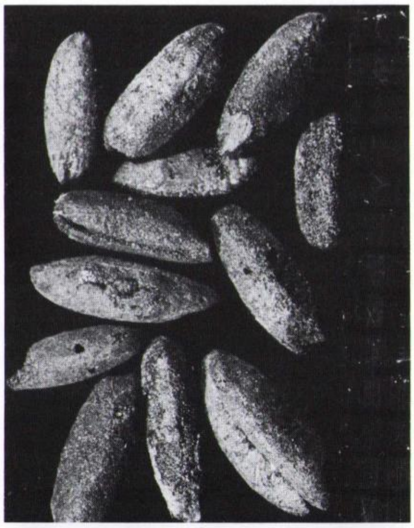


*Figure 3: Charred grains of wild-type einkorn wheat (*Triticum boeoticum*) from early Mesolithic levels at the Syrian site of Tell Abu Hureyra.*

Low dimensional structure growth centres

The Molecular Beam Epitaxy (MBE) Centre based at Nottingham University was formally inaugurated on 18 January 1988 in the presence of the Rt Hon Kenneth Clarke, Chancellor of the Duchy of Lancaster. The Centre is supported by SERC Physics Committee grants totalling more than £2.2 million.

The Nottingham University MBE Research Syndicate (NUMBERS) is based on equipment manufactured by Varian and has almost 50 research workers in Nottingham, with colleagues in Glasgow, Hull and Warwick Universities and others at industrial and government laboratories. Nottingham is one of six such growth centres; the others are at Hull, Imperial College of Science and Technology, Warwick and Cambridge all using MBE, with one at Oxford using metallo-organic chemical vapour deposition (MOCVD).

Nottingham's research programme associated with this facility is wide ranging but coordinated. It includes experimental and theoretical work on electron-phonon interaction, quantum transport, quantum tunnelling, hopping and submillimetre and optical properties. Samples produced at Nottingham consist primarily of GaAs epilayers and GaAs/AlGaAs heterojunctions. The layers produced to date include one with the highest mobility ever produced in a university laboratory (2.1 million $cm^2V^{-1}s^{-1}$ at 4K).

A number of structures including superlattices and resonant tunnel structures have been produced for the associated research groups and external collaborators.

These growth centres are the principal elements of the Science Board's special programme in low dimensional structures (LDS). The centres provide the precise, complex semiconductor samples needed to explore the novel physical properties that arise when electronics in a solid are no longer free to move in three dimensions. They require large equipment, staffing and running costs. In each of the six cases approved so far, the university has agreed to provide staff posts, a contribution to the capital costs and dedicated clean room facilities. The MOCVD equipment at Oxford began operating in February 1986 and the MBE equipment at Cambridge in September 1986, at Imperial College in March 1987 and at Hull in May 1987.

The LDS programme

The LDS programme is the first and so far the largest of a number of coordinated Science Board initiatives intended to support strategic research in new, exciting areas of science. Professor John Beeby of Leicester University was appointed Coordinator of the LDS programme in September 1985 (see *SERC Bulletin* Volume 3 No 3, Autumn 1985). Already more than £12 million has been committed from SERC funds for LDS research in 25 universities and a further £7.5 million has been included in the forward look budget over the next two years.

The properties of LDS, which are formed from very thin layers of semiconducting materials, are varied and strikingly different from those of bulk semiconductors. New electronic, optical and magnetic properties are being discovered and many possibilities exist for technological exploitation.

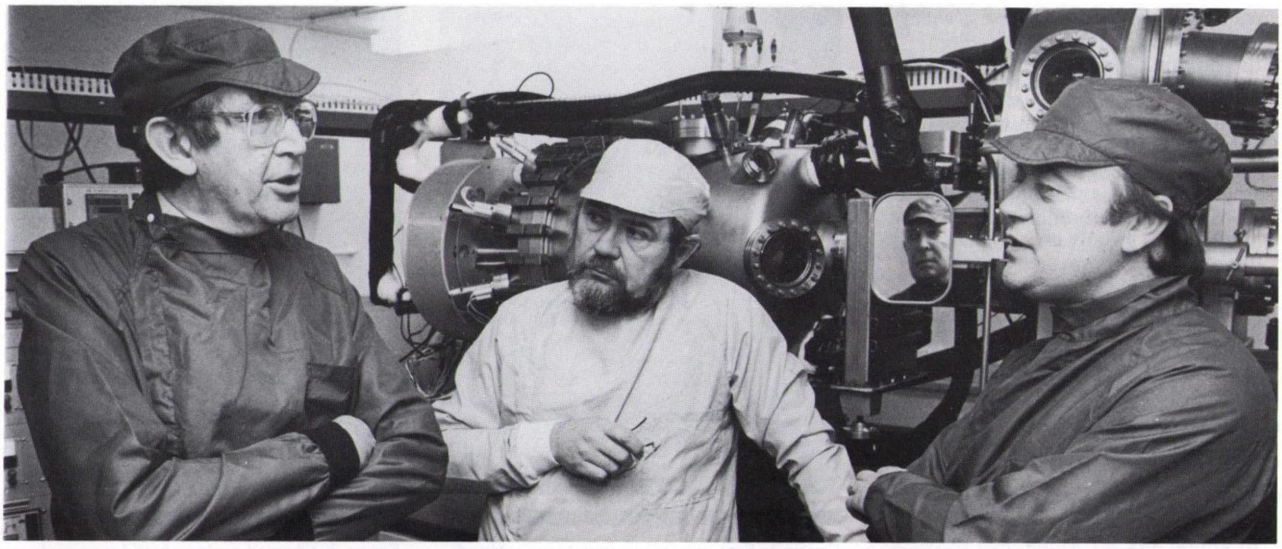
The LDS programme aims to study the new science of such structures, enhance the interactions between the academic community and industry, and provide urgently needed, highly trained scientists for industry.

The UK electronics industry attaches great importance to LDS research in universities, and companies have already provided more than £2.5 million to the programme through cooperative research grants, CASE studentships, the supply of specimens and the training of key growers.

SERC's Science and Engineering Boards recently agreed to develop a joint LDS and devices programme in which the physics emerging from LDS will be used to develop novel semiconductor devices.

SERC is liaising closely with UK industry, the Department of Trade and Industry and the Ministry of Defence in the management of these national programmes. The maintenance of a strong research effort is vital if the UK is to maintain and improve its position in the face of fierce competition from Japan, the UK and Western Europe.

Miss J Williams
SERC Swindon Office



Inauguration of the Molecular Beam Epitaxy Centre at Nottingham University, January 1988. Left to right: Professor L J Challis (the principal investigator), Dr O H Hughes (an MBE grower) and the Rt Hon Kenneth Clarke, MP.

Total technology at Manchester

In December 1987, the University of Manchester Institute of Science and Technology celebrated the tenth anniversary of their Total Technology programme by inviting to lunch more than 140 past and present students and the academics and industrialists involved in the Scheme. Sir Hugh Ford, originator of the Scheme, was present and must have been extremely proud to see the obvious enthusiasm and liveliness of the community he helped to bring about.

In the speeches which formed the centrepiece of the occasion, Professor G C Wood and Dr Ray Leonard of UMIST described the history and workings of the scheme; Mr Peter Neal, an ex-student now working with IBM, spoke of the great benefit he had received from such a broadly based postgraduate education, and Professor A Thomson, Chairman of the Joint Economic and Social Research Council-SERC Committee, gave a summary of the Committee's proposals for an expansion of the scheme and their relevance to the current debate on the need for a different type of engineering PhD.

Although the Total Technology Scheme has been in operation since the mid 1970s, it is not one of the largest or best known of SERC's postgraduate training endeavours, having been somewhat overshadowed by later schemes such as CASE (see page 24), the Teaching Company and Integrated Graduate Development Schemes. Through the Total Technology Scheme, the Joint ESRC-SERC Committee allocates about 35 research studentships a year to five recognised Total Technology centres, the aim being to give young engineers a thorough training in all aspects of the technological process within industry so that they quickly become effective and practical engineers.

A typical TT student carries out a research project on an industrial problem within a firm under joint academic and industrial supervision. The projects encompass the broader financial, organisational, management or social aspects, and a fundamental aspect of the training is that students attend courses of lectures on these wider issues. Collaborating firms are expected to supplement the student's grant up to a maximum of £2491 a year. At the end of three years' study, a successful TT student will not only have a PhD based on a research project carried out within an industrial environment, but will also have received formal training in the management and financial aspects essential in an engineering career.

UMIST currently mounts the largest Total Technology programme supported by SERC. It has 50 current TT students based in more than 16 academic departments at UMIST and Manchester University. More than 40 industrial companies have participated in the programme. In addition to UMIST there are recognised centres at Aston and Newcastle Universities, the University of Wales Institute of Science and Technology and Cranfield Institute of Technology.

For further details about the Total Technology Scheme, please contact Dr Maggie Wilson, Total Technology Secretariat, at SERC's Swindon office, ext 2238.

Research councils in Europe

The increasing importance of the European dimension in scientific research has been recognised by the five UK research councils with the setting up of a new joint office in Brussels.

The joint initiative will take advantage of and build upon the experience of the Natural Environment Research Council which set up an office in 1984 in recognition of the need to improve the two-way flow of information between NERC establishments and the officials of the European Commission.

With effect from January the other four research councils — Science and Engineering, Agricultural and Food, Medical, and Economic and Social — have agreed to share the costs and advantages of running an expanded joint office. This would accord both with the Advisory Board for the Research Councils' strategy for greater European cooperation and with the research councils' aims to increase their European research over and above their present levels.

All the councils have interests in the development of European policies and research initiatives, and take part as partners or contractors in European programmes. There are considerable sums of money available from the Commission for research and development, but one of the problems for the councils as potential contractors and European partners is finding out the relevant information about the programmes at the right time.

The need for a good information flow is vital and the councils' new initiative provides a 'listening post' for advance information, can follow up the fate of proposals made and provides practical assistance and support for individual visits to Brussels.

An important role of the office will be its continued and growing links with higher education estabishments through the 'Brussels Club'. This means that some services of the office are available to higher education institutions for an annual subscription.

These services include:

- A regular newsletter providing a summary of funding opportunities available from the EC, plus appropriate further information.
- Advice about key people to approach in the Commission and help in dealing with specific enquiries.
- The follow-up of proposals and feedback on their evaluation.
- Help with visits to the EC both in planning and during the visit.
- An annual seminar for members, dealing specifically with live opportunities and issues.

Management of the joint office will be a NERC responsibility, staffed by two officers and a secretary, and will be controlled by a joint steering committee.

Alvey Vision Conference

The award for the best paper given at the third Alvey Vision Conference, held at Cambridge University in September 1987, was made to C G Harris and J M Pike of Plessey Research for their paper on *3D positional integration from image sequences.*

The fourth Alvey Vision Conference will be held at Manchester University from 31 August to 2 September 1988. Its prime function is to provide a forum for the presentation and discussion of technical reports on Alvey-funded — and other — work in computer vision and image interpretation. In view of the increasing importance of EEC programmes, it is hoped to include additional papers from members of ESPRIT consortia.

Those wishing to attend AVC88 should send a completed registration form, with full payment, to Helen Jenkins, AVC88, Rutherford Appleton Laboratory, telephone Abingdon (0235) 445840, by 14 August at the latest.

Some further CASE studies

In the last issue of the *SERC Bulletin* (Volume 3 No 10, Spring 1988) we published short accounts of some projects undertaken by research students in the Cooperative Awards in Science and Engineering scheme. Here we bring you some more of these CASE studies.*

Defects in steel investment castings

Deritend Precision Castings Ltd (DPC), after many years of successfully producing general engineering components, encountered difficulties in quality control following a move into high integrity markets such as the Ministry of Defence, nuclear and mining. Although suitably qualified staff were present in the company to study the casting process and to establish the causes of the defects, commercial constraints on time precluded long-term scientific investigations.

Discussions between DPC Ltd and the Department of Mechanical and Production Engineering at Aston University on the various ways of funding cooperative research led to a CASE proposal being drawn up. Phil Whateley, a student with a good honours degree in Material Technology and several years' experience in research and development, was selected and began the project in December 1985.

Mr Whateley spent the first two months at DPC Ltd, looking at production of castings in detail, and planning a programme of defect identification and characterisation. In the second stage, extensive use was made of optical and electron metallography facilities at Aston, over a period of about a year. The major academic aspect of the project involves establishing the mechanisms of defect formation through experimentation, modelling and works trials, to provide the required firm foundation to the introduction of process modifications to eliminate the defects.

DPC Ltd already consider the collaboration to be a success. The CASE project has given them a well qualified man with a fresh approach who, by virtue of not being on the payroll, was not diverted from prearranged tasks. The company made a considerable input to the project to be sure that it has proceeded along the right lines and to gain as much as possible from the investigation. Already there has been a considerable reduction in the scrap rate of certain high integrity castings.

A bonus arising from the project was the beneficial effect of the regular contact between its technical and managerial staff and the academic staff at the University. The company feels that the CASE scheme offers excellent value for money in allowing it to update its technology.

Brian Page, the industrial supervisor, Rex Delicate, DPC Ltd's Personnel and Training Manager, and Phil Whateley, the research student, inspecting a mould at DPC Ltd.

Degradation and stabilisation of 'new process' polyolefins

This CASE proposal was drawn up when ICI had completed developing new process technologies for the manufacture of polyolefins, now quite widespread throughout the polymer industry. At that time, methods of polymerisation resulted in polymers with high and variable levels of catalyst residues, and a CASE project at Manchester Polytechnic was set up to pool expertise to investigate the extent and cause of the problem.

The student, K Fatinikun, was already known by the Polytechnic to be well qualified for the project, having graduated with an MSc from Salford University in this area of work.

Fruitful project

The project was fruitful to both partners: the Polytechnic had facilities which ICI did not have at that time, and ICI were able to provide many necessary materials, including a wide range of polymer materials unobtainable from other sources. This was a true collaboration in which the academic research was grounded in real needs and problems of industry.

The student spent a number of weeks preparing polymers and evaluating their properties at ICI and the company gave considerable analytical support; for example, X-ray analysis on a routine basis which a PhD student could not cope with.

The project was successful in achieving its aims in sorting out the problem and to some extent providing a solution as well as a new approach to examining the problem in future. The results were commercially sensitive but there was a mutual agreement on publication and about six papers have been produced.

**From material supplied by L W Crane, Aston University; Dr N S Allen, Manchester Polytechnic; Professor D J Barber, Essex University; and Professor M J H Sterling, Durham University.*

Electrical properties of perovskite-structured crystals

This CASE project arose from joint recognition by Essex University and the Plessey Company that many of the macroscopic properties of ferroelectric perovskite-type oxides have their origins in processes occurring at the submicron or atomic level. Such microprocesses appeared to be particularly appropriate for investigation by the methods of transmission electron microscopy (TEM). Yet when the project was proposed, little work of this sort had been published, and what had been was concerned mainly with model compounds rather than materials of commercial interest. Obvious points for investigation included the nature of paraelectric-ferroelectric phase transitions, whether ferroelectric domain configurations and their dynamics were affected by defective microstructures, and the possible occurrence and effects of any second phase in sintered ferroelectric oxides.

When the academic supervisor approached Plessey's Allen Clark Research Centre (ACRC), he had just returned from a visit to the Materials Research Laboratory at the Pennsylvania State University, where a large group was working on ferroelectric materials under the leadership of Dr Eric Cross. Contacts existed between Dr Cross's group and ACRC, making ACRC the obvious UK laboratory to approach.

The early stages of the project required the student, Clive Randall, to become reasonably expert in TEM techniques and diffraction theory, in addition to gaining a basic understanding of the behaviour of modern ferroelectric materials. He was diligent in acquiring this knowledge and began to make significant observations within six months of the project starting. It was undoubtedly of great benefit that ACRC had the materials technology well under control and was able to supply a variety of electrically well characterised materials. Because of other CASE studentships, good X-ray data was also available on some samples and there was also access to single crystal samples made for other purposes.

Topics studied during the three-year period included the switching behaviour of ferroelectric domains, materials which transform to a rhombohedral structure on becoming ferroelectric, the origins of diffuse scattering in relaxors, interactions between ferroelectric domain configurations and 'normal' microstructure. Four papers are either published or in press, and two further publications are likely to stem directly from the results obtained.

The success of the work led to Clive Randall receiving an invitation to work with Dr Cross's group at the Pennsylvania State University during his third year. The visit has helped to consolidate links between Pennsylvania, Essex and ACRC. The success of this CASE studentship resulted in another CASE submission being made to SERC by ACRC and Essex for research on related topics and the application was successful. Another direct result has been a successful research grant application for work on thermal detector materials under the SERC/Ministry of Defence scheme. ACRC are also supplying materials for this research and expect to use the results. This fruitful CASE studentship has stimulated much activity in the important area of ferroelectric and relaxor materials, and forged a strong new university-industry link.

Load frequency control

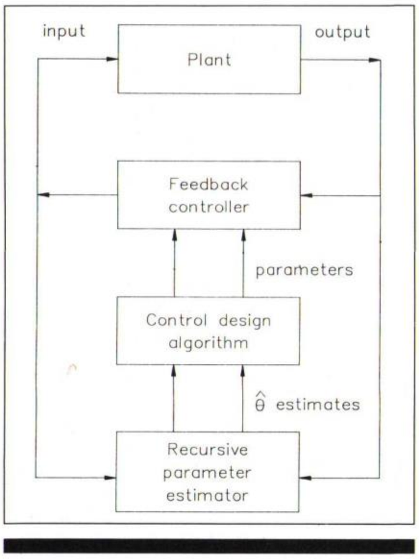
This CASE project was set up between the Central Electricity Generating Board and the School of Engineering and Applied Science at Durham University, against the background of the Operational Control of Electrical Power Systems research programme, which creates an environment in which a real-time power system can be accurately modelled and in which control action can be implemented. The package enables real-time control and simulation of realistic situations which would be encountered daily by power system control engineers.

In a power system, the consumption varies with the time of day, and so the aim of the control engineer is to satisfy the demand in the most economic and secure manner, within the limits of frequency and voltages set up by the authority. The medium range optimisation (above 30 minutes) is carried out by despatching routines. However, as the load varies and cannot be predicted exactly, a faster acting control is required (about 10 seconds) for the fine tuning of the system. This short-range control is termed 'load frequency control'.

The conventional way in which load frequency control has been implemented is the use of proportional plus integral (P+I) control action. This enables abrupt changes to be responded to as well as any long-term deficiencies.

The student chosen for the project was Alan Birch, and he has been working on the design of a self-tuning regulator to replace the present standard P+I controller. The self-tuning regulator is a good alternative to the conventional controller, since it offers versatility and the ability to operate in a real-time environment. Up to now, the self-tuning regulator theory has been applied to only relatively few real-time systems, mainly in the chemical industry.

The student used the full dynamic simulator and adaptive load frequency control to observe the effects of the varying parameters on the performance of the power system as a whole. The parameters considered included the sampling period, the order of the model under study, the effects of various algorithm coefficients and a varying weighting factor. He also made system studies into the tracking of the parameters to ensure that they were stable and that convergence was always possible. To test the value of the adaptive technique, the generator gains were increased by a factor of 2 and the resulting effects were compared with those of the original P+I controller. It was found that the new control scheme could adapt to the gain change and control the units with the same time-response as in the previous case, whereas the P+I controller caused severe transients in the system. Scenarios to simulate generation and load-loss have been applied to the system and the response of the controller and the system have been observed. Work will continue into stability and robustness of the control scheme, especially under steady-state conditions where the parameters could drift.



Structure of self-tuning regulator.

Studentship numbers 1987-88

1987 report

In 1987 the Boards and specialist Directorates allocated 4910 studentships (compared with 4945 in 1986). Of these 1705 lay within the field of Information Technology.

By 1 November 1987, a total of 4700 awards had been taken up. The demand at the 'appeals' stage with 644 eligible candidates was similar to that in 1985 and 1986. All candidates with first class honours degrees were successful in obtaining an award.

The numbers of nominations for Cooperative Awards in Science and Engineering (CASE) were disappointing, especially in Engineering where take-up by 1 November 1987 of 149 fell some 35% short of the target of 230 (see Table 1). The removal of a closing date in 1986, while of benefit in that year in producing a late surge of nominations, has in 1987 failed in the Engineering and Information Technology fields to have had a similar effect — indeed, its removal may even have proved to have been counterproductive. The Council greatly values the CASE scheme and has for that reason endeavoured to make the approach to CASE nominations as flexible as possible. It is thus not intended to reinstate the closing date for CASE nominations, to make sure CASE studentships are not neglected at the expense of quotas of standard research studentships, but the Council is studying the matter. Meantime, Department Heads have been urged to submit CASE nominations as quickly as possible, preferably at the same time as for standard research awards, that is, during the summer.

At the request of the Department of Education and Science and in compliance with European Community legislation, eligibility for awards was extended in 1987 to those candidates who were nationals of other member states of the European Community and who at the date of application were ordinarily resident in the Community. Awards to these candidates are, however, only required to provide tuition fees, and 54 awards fell into this category. The details are as follows:

Engineering	20
Science	8
Biotechnology	1
Information Technology	25

Of the 54 awards taken up, 29 went to Greek nationals and 11 to residents of the Irish Republic.

Table 1: Distribution of 1987 awards taken up by 1 November 1987

(1987 targets agreed by Boards in brackets)

	APS	Engineering	IT	NP	Science	Biotech-nology	TOTAL
Research studentships							
Standard	70(73)	284(310)	310(295)	56(55)	959(939)	35(42)	1714(1714)
CASE	7(6)	149(230)	112(130)	8 (7)	402(423)	43(53)	721(849)
Instant	3(3)	12(19)	6(10)	1(2)	62(70)	--(--)	84(104)
Total RS	**80(82)**	**445(559)**	**428(435)**	**65(64)**	**1423(1432)**	**78(95)**	**2519(2667)**
Advanced course studentships							
Standard	21(21)	463(510)	327(300)	--(--)	304(313)	21(22)	1136(1166)
Instant	-(1)	43(54)	42(50)	--(--)	20(21)	--(--)	105(126)
Conversion	--(--)	--(--)	919(915)	--(--)	--(--)	--(--)	919(915)
Total ACS	**21(22)**	**506(564)**	**1288(1265)**	**--(--)**	**324(334)**	**21(22)**	**2160(2207)**
Awards tenable overseas	**1(3)**	**9(19)**	**2(5)**	**--(--)**	**6(6)**	**--(--)**	**21*(36)***
TOTAL	**102(107)**	**960(1142)**	**1718(1705)**	**65(64)**	**1753(1772)**	**99(117)**	**4700*(4910)***

*Includes 3 overseas awards outside the Council's field, resulting from SERC's obligations to NATO

Table 2 : Allocations decided by Boards for 1988

	APS	Engineering	IT	NP	Science	Biotech-nology	TOTAL
Research studentships							
Standard	72	310	275	55	966	40	1718
CASE	6	230	150	7	381	45	819
Instant	3	19	10	2	70	-	104
Advanced course studentships							
Standard	18	544	300	--	337	20	1219
Instant	1	54	50	--	21	--	126
Conversion	--	--	915	--	--	--	915
Awards tenable overseas	3	0	5	--	6	--	16*
TOTAL	**103**	**1157**	**1705**	**64**	**1781**	**105**	**4917***

*Includes 2 overseas awards for provision outside the Council's field in consequence of SERC's responsibilities to NATO.

Plans for 1988

Reviews of applications for quotas of research and advanced course awards are now carried out on a biennial basis with bids for quotas of advanced course awards alternating with those for research. As 1988-89 is the bye year for standard research awards, the 1988-89 quota allocation is substantially unchanged from the provision for 1987-88, except for a modest increase in provision by the Science Board to cover special initiatives. On the advanced course front, in 1987 demand for Information Technology awards remained buoyant and the high level of support has been maintained for 1988-89. The Engineering Board has provided some additional support in advanced course studentships for manufacturing systems engineering. There will be no peer review of advanced course proposals next year as under the biennial review system the Council will rely on the decisions taken this year.

The overall picture is thus one of maintaining, at an historically high level, Council's support of postgraduate training. Awards for 1988-89 will total 4917 compared with the Boards' provision last year 4910.

Table 2 sets out the distribution of studentships to be made in 1988.

PhD submission rates

Studentship awards beginning in 1983

The Council views the writing up of theses within a reasonable time as an effective measure of the satisfactory completion of a student's training. The determination of a department's quota is influenced by its rate of submissions and, in 1987, 41 departments were sanctioned because of a particularly poor submission rate. Standard research quota allocations are now made on an biennial basis, the 1987 allocations standing with only minor adjustments for 1988; sanctions applied in 1987 thus continue to apply for 1988.

Following an observation by the National Audit Office, the Heads of Research Councils have agreed to standardise the approach to the derivation of submission rates. With effect from 1987, data will be sought on students who did not withdraw in the first year and who submitted for either a PhD or a masters. The rate is now measured as the number of submissions as a percentage of those who started. No future regard will be had to the numbers of students remaining registered to submit. SERC is also required to collect the data four years after the start of the award, and at the fifth and sixth year points.

The tables below set out the results of the latest survey — the eighth in the series — showing the submissions for theses by 1 October 1987 by SERC-funded research students whose awards began in 1983.

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

Table 1: PhD submission rates by institution

	No of students starting 1983	No submitting by 1.10.87
Universities of England:		
Aston	40	21
Bath	46	33
Birmingham	72	51
Bradford	28	13
Bristol	56	29
Brunel	12	11
Cambridge	167	107
City	17	11
Cranfield Institute of Technology	21	12
Durham	36	23
East Anglia	20	9
Essex	11	6
Exeter	21	15
Hull	19	9
Keele	9	6
Kent	25	18
Lancaster	20	13
Leeds	78	50
Leicester	37	18
Liverpool	50	31
London Colleges		
Birkbeck	13	9
Goldsmiths	1	1
Imperial	164	97
King's	15	9
King's (Chelsea)	9	4
King's (Queen Elizabeth)	17	12
Queen Mary	37	14
Royal Holloway & Bedford New	16	11
University	63	33
Westfield	1	1
Wye	4	3
Other institutions	25	16
Loughborough	19	8
Manchester	87	60
UMIST	84	47
Newcastle	37	24
Nottingham	75	48
Open	8	5
Oxford	157	124
Reading	27	17
Salford	23	13
Sheffield	66	37
Southampton	64	42
Surrey	34	12
Sussex	34	21
Warwick	37	22
York	19	14
University of Wales:		
Aberystwyth	16	10
Bangor	13	8
Cardiff	22	16
Swansea	27	15
UWIST	12	5
Universities of Scotland:		
Aberdeen	20	16
Dundee	12	8
Edinburgh	75	48
Glasgow	55	38
Heriot-Watt	23	8
St Andrews	18	9
Stirling	8	2
Strathclyde	40	19
Total universities	**2262**	**1392**
Total polytechnics*	**101**	**47**
Other institutions*	**12**	**6**
Grand total	**2375**	**1445**

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

Table 2: PhD submission rates etc by SERC Board

	No of students starting 1983	No submitting by 1.10.87
Science Board:	1238	822
Biological Sciences	*465*	*302*
Chemistry	*482*	*336*
Mathematics	*124*	*79*
*Physics, Neutron Beam and SBA**	*167*	*105*
Engineering Board	945	505
APS Board	78	48
NP Board	64	41
Biotechnology Directorate	50	29
Grand total	**2375**	**1445**

*SBA — Science-based Archaeology

Some new publications from SERC

All these publications are available, free, from SERC Swindon Office.

Nuclear structure
Copies of the *Nuclear Structure Committee annual review* are available from the Committee Secretariat, ext 2223.

Civil engineering
Civil engineering: Summaries of research reports, September 1987: Copies are available from ext 2493.

Process engineering
Copies of two reports are available from the Process Engineering Secretariat, ext 2400. They are: *Grants current at 1 July 1987* and *Selective adsorption*, a report by B T Crittenden within the Separation Processes Initiative of the Process Engineering Committee and the Biotechnology Directorate.

Astronomy
Large Telescope Panel report: a report to the Astronomy and Planetary Science Board on the possibilities for UK involvement in future optical and infrared telescope programmes. Copies available from Dr A G Game, ext 2417.

Core science
The second edition of *A strategy for support of core science* is available from Mrs J Hobson, ext 2314.

Interfaces and catalysis
An introduction to the interdisciplinary *Interfaces and Catalysis Initiative*, with summaries of current research, is available from Dr A Le Masurier, ext 2263.

Chemistry
Copies of *Current grants in Chemistry, October 1987* are available from Miss J Mason, ext 2126.

Royal Greenwich Observatory: steps along the road to Cambridge

Good progress is being made towards the move of the Royal Greenwich Observatory to a site on the campus of the Institute of Astronomy (IoA), Cambridge. The authorities of Cambridge University have approved the release of the site; an attractive new building has been designed; planning permission has been received; and discussions are well under way between the RGO and the IoA on likely areas of fruitful association. These events reflect not only the great commitment and contribution of SERC's Council Works Unit, which is managing the building project, but also the work put in by RGO Management, and the constructive cooperation of the IoA and the University authorities.

The new building

The new building will house some 100 employees in 4,400 square metres of floor space. In addition to offices there will be workshop and laboratory facilities to match foreseen requirements, and flexibility to adapt to future changes. The total cost is likely to be around £3 million. Given no undue delay in completing the tender exercise, and in obtaining approval from the Department of Education and Science, construction will start around September this year. The relocation might then be expected to take place during the first half of 1990.

Sale of Herstmonceux Castle and estate

The property in East Sussex, which amounts to 380 acres, will be marketed by Knight, Frank and Rutley, in three lots: the Castle, gardens, woodland and farmland; the West Building, adjoining buildings and immediate surroundings; and the Equatorial Group of six telescopes which houses the main exhibition. (It will be made clear that the local authorities and tourist organisations are interested in the Equatorial Group remaining a public attraction). A study into leisure development options was jointly financed by the tourist boards and local authorities and SERC, and its conclusions have been made known to Knight, Frank and Rutley.

Staffing of the RGO

Independently of relocation, RGO must achieve complement reductions from the present level from 190 to 135 by 1990-91.

It is nevertheless expected that almost all mobile staff who wish to remain with RGO on relocation will be able to do so.

There will also be chances for staff in lower grades to transfer. This does not, of course, alter the fact that the uprooting of an organisation has a profound effect upon many lives. For example it looks inevitable that there will be redundancies. The Official and Trade Union Sides of RGO, through the Relocation Tripartite Committee, are discussing ways of easing the transition for staff who transfer to Cambridge, and maximising the options open to those who do not. Discussions will also be held with the eventual purchaser of the castle and estate to examine opportunities for the engagement by them of non-mobile staff being made redundant.

Early moves

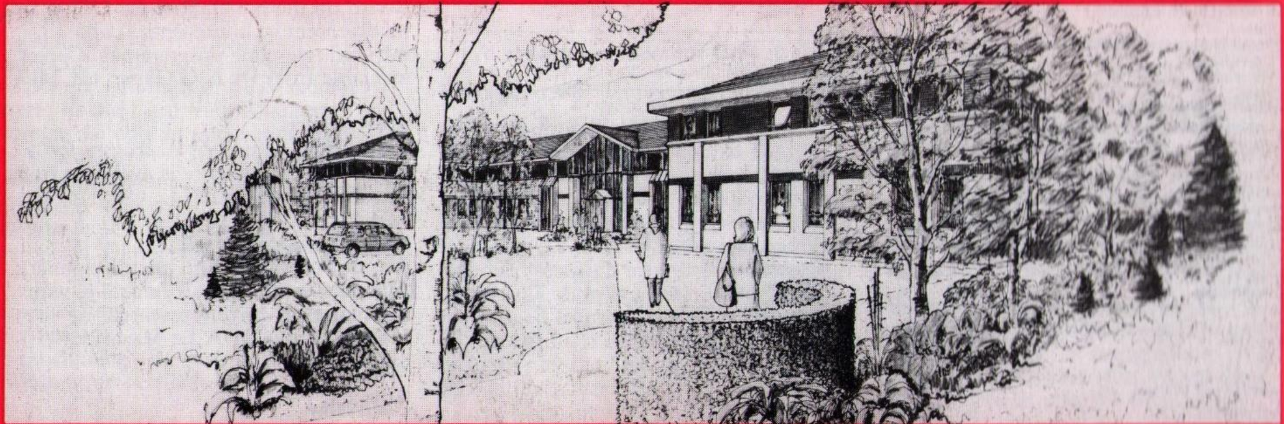
The teams providing RGO's contribution to the HIPPARCOS satellite project and the Carlsberg Automatic Meridian Circle are transferring to Cambridge in August 1988. This is because the HIPPARCOS team require a stable base during the period when the satellite will be transmitting data; the CAMC team are accompanying them for operational reasons. Until the new building is ready for occupation, they will work in temporary accommodation at the IoA.

Association with the University

Among the benefits to be obtained from the relocation are economies of operation and enhancements of effectiveness through synergy, with the Cambridge University in general, and the IoA in particular. Talks about operational arrangements are, for example, under way for the formation of a joint RGO/IoA Starlink node. Appropriate parts of the RGO's archives and historical collections, which the new RGO building will not be equipped to house, will be accommodated by the Cambridge University Library.

Both the RGO and the IoA are anxious to achieve maximum coordination of scientific activities, and discussions are under way. In the administrative area there are prospects of mutual benefit through association in site administration and services, and through sharing of staff facilities.

Peter Bradbury
Royal Greenwich Observatory



How the new Royal Greenwich Observatory, Cambridge, is expected to look.