SERC BULLETIN

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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. *SERC Bulletin* summarises SERC policies, programmes and reports. Enquiries and comments are welcome and should be addressed to the editor, Miss J Russell, at the Science and Engineering Research Council, Polaris House, North Star Avenue, Swindon SN2 1ET; tel Swindon (0793) 26222.

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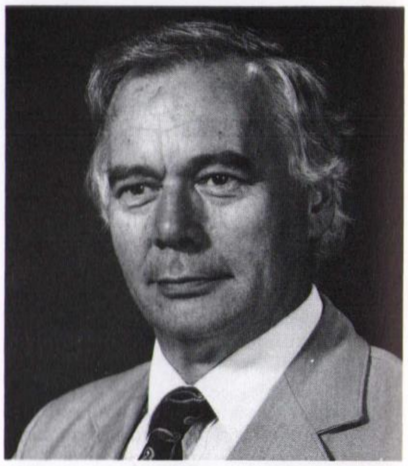
Professor Bill Mitchell, new Chairman of SERC

Professor E W J Mitchell CBE has been appointed Chairman of the Science and Engineering Research Council by Sir Keith Joseph, Secretary of State for Education and Science, for a period of five years from 1 October 1985. He succeeded Sir John Kingman FRS, who took up his appointment as Vice-Chancellor of Bristol University on 1 September.

Until his appointment, Professor Mitchell was Head of the Clarendon Laboratory, Oxford. Since 1978 he has been the Dr Lee's Professor of Experimental Philosophy at Oxford University and a Fellow of Wadham College. Between 1976 and 1978 he was Deputy Vice-Chancellor of Reading University.

Bill Mitchell graduated from Sheffield University in 1945 and, after a period with Metropolitan Vickers, gained his PhD from Bristol in 1950 for measurements of the work function of metals and semiconductors. He joined Reading University in 1951 and worked on a succession of topics in solid state physics — colour centres in quartz and diamond, radiation damage, the Faraday effects for determining effective masses in semiconductors, highly disordered gallium arsenide and the development of the now widely used method of small angle neutron scattering for the study of real crystals. He has recently been studying the structure and dynamics of simple molten salts, using neutron and light scattering.



Professor E W J Mitchell CBE

Professor Mitchell has been closely associated with the work of SERC for several years. He served on the Council from 1970 to 1974 and from 1982; he was Chairman of the Physics Committee from 1967 to 1970 and the Neutron Beam Research Committee from 1967 to 1974. He was awarded the CBE in 1976.

Director appointed for ACME

William E Hillier has been appointed as Director of SERC's ACME (Application of Computers to Manufacturing Engineering) Directorate, from 9 September 1985.

Mr Hillier has held a number of senior positions with various companies, including Texas Instruments and Racal Redac, and was responsible for evaluating new business opportunities in the computer integrated manufacturing field for Racal Electronics. He has a wide knowledge of the manufacturing industry in large and small companies, both in UK and in USA, and has considerable managerial experience. He is a Chartered Engineer, a Member of the Institution of Electrical Engineers, a Fellow of the British Institute of Management and holds an Open University degree in Mathematics and Psychology.

William Hillier

Front cover picture

Queen Beatrix of the Netherlands and HRH Duke of Gloucester watch with amazement and delight as the Isaac Newton Telescope and its dome rotate in opposite directions during the inauguration ceremonies on La Palma. In the background is President Weizsacker of West Germany and on the left is Professor Alex Boksenberg FRS, Director of the Royal Greenwich Observatory and President of the International Scientific Committee for La Palma and Teide. ***Story: see page 21.***

Council commentary

Instrumentation for the Spallation Neutron Source

In April Council approved a proposal for the construction of a neutron diffractometer for amorphous and liquid samples for the Spallation Neutron Source at the Rutherford Appleton Laboratory.

Council Panels

Following its policy of undertaking special reviews of important areas of its interests, Council has agreed to set up panels (i) to consider future arrangements for its support in the UK of the overseas facilities for ground-based astronomy, regarding both management and location, (ii) to review the activities of the Council in the support of biotechnology.

Collaboration between the Council and the Ministry of Defence

Following the Prime Minister's seminar on science, technology and industry, Government has given consideration to ways in which the science base in the UK could be strengthened through increased support to university research by the Ministry of Defence. One outcome is that a scheme is now being devised by which MOD and SERC will jointly contribute to the funding of research grant programmes in which each has an interest.

Forward Look 1986/87 - 1988/89

At its meeting in May, Council received the version of its Forward Look which has been sent to the Advisory Board for the Research Councils. This set out a core of activities which are considered to be of such importance that they must be given the resources needed for proper exploitation; those outside the core will be given urgent consideration to reduce drastically the amount now being spent on them. Subsequently Council submitted its bids for additional funds to be provided from the ABRC's 'flexibility margin', whose purpose is to permit changes in the distribution of the Science Budget to reflect new developments and new priorities.

Corporate Plan

In recent months Council has given attention to the preparation of its Corporate Plan, a policy statement covering a longer period than that of the Forward Look. It is expected that the document will be finalised towards the end of this year.

Major new grants

Approved by Council, April - July 1985

ASTRONOMY, SPACE AND RADIO

Professor J L Culhane (University College London): up to £781,000 over one year for space research at the Mullard Space Science Laboratory

Professor F G Smith (Manchester University): up to £552,000 over one year for radioastronomy research at Jodrell Bank

Professor K A Pounds (Leicester University): £524,000 over one year for research on Xray astronomy and astrophysics

Professor A Hewish (Cambridge University): £446,000 over one year for support of the Mullard Radioastronomy Observatory

Professor M J Rees (Cambridge University): £374,000 over four years for research in theoretical astronomy

ENGINEERING

Professor A P Anderson, Dr J C Bennett and Dr B Chambers (Sheffield University): £325,000 over four years for research on microwave and millimetre wave antennas, image diagnostics and digital image processing

Professor J Lamb (Glasgow University): £481,000 over four years for research in thin film optical waveguide devices and systems

Dr M H Lee and Dr N W Hardy (UCW, Aberystwyth): £400,000 over three years for research on a software development package for intelligent supervisory systems

Professor F J Bayley and Dr J M Owen (Sussex University): £379,600 over three years for research on heat transfer and fluid dynamics of gas turbines

Professor E A Ash, Professor D E N Davies and Professor J E Midwinter (University College London): £681,800 plus the use of SERC facilities over four years for support of the microwave research unit

Professor W A Gambling and Dr D N Payne (Southampton University): £536,000 over four years for research on optical fibres and their applications

SCIENCE

Professor A Pelter and Dr J A Ballantine (University College, Swansea): £611,800 over four years for the establishment of an SERC Mass Spectrometry Centre in Swansea

Dr B C Cavenett et al (Hull University): £790,000 for research on semi-conducting magnetic superlattices

Dr G C K Roberts and Professor W V Shaw (Leicester University): £329,000 over four years for research on high field NMR studies of protein specificity

NUCLEAR PHYSICS

Grants of three years' duration to particle physics experimental groups at: Birmingham University (up to £698,000), Cambridge University (up to £492,000), Glasgow University (up to £744,000), Imperial College (up to £1,059,000), Liverpool University (up to £588,000), Manchester University (up to £581,000), Oxford University (up to £945,000), Queen Mary College (up to £375,000), and University College London (up to £567,000).

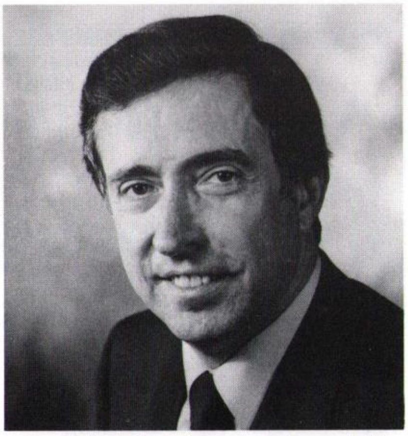
Congratulations

...on their election to the Fellowship of Engineering to:
David A Claydon (BP Group Engineering and Technical Centre), member of the Marine Technology Management Committee;
Dudley Dennington (F R Bullen and Partners), member of the Environment Committee;
Professor Peter Dunnill (University College London), member of the Biotechnology Management Committee and the Process Engineering Committee; and
Clive A P Foxell (British Telecom plc), member of the Information Engineering Committee and Chairman of the Microelectronics Facilities Subcommittee.

Eight appointments to Council

Sir Keith Joseph, Secretary of State for Education and Science, has appointed eight new members to the Science and Engineering Research Council. They are Professor D E N Davies FEng, FRS, Professor B E F Fender CMG, Mr R B Horton, Professor M A Jeeves, Professor D H Perkins FRS, Dr C H Reece, Mr D T Shore OBE, FEng and Professor R Wilson CBE, FRS. They replace Professor D C Colley, who resigned on 3 January 1985; Professor J I G Cadogan CBE, FRS, Sir Diarmuid Downs CBE, FEng, FRS, Mr P A B Hughes CBE, Professor A G J MacFarlane FEng, FRS, Professor M H Richmond FRS and Professor W L Wilcock, who retired on 31 July 1985, and Sir Francis Tombs FEng has resigned upon his appointment as Chairman of the Advisory Council for Applied Research and Development. The new appointments took effect from 1 October 1985 and will run until 31 July 1989. In addition, Dr M W Holdgate CB, Chief Scientist at the Department of the Environment, has been reappointed for a further term.

Professor Davies is Professor of Electrical Engineering at University College London. He was previously an Assistant Director in the Research Division of British Railways Board, Derby, where he was responsible for work on communications, signalling and automation. Having obtained his PhD from Birmingham University in 1960, 'Den' Davies spent six years as a lecturer and senior lecturer in the Electrical Engineering Department there and was also involved in a staff interchange scheme with the Royal Signals and Radar Establishment, Malvern. His fields of

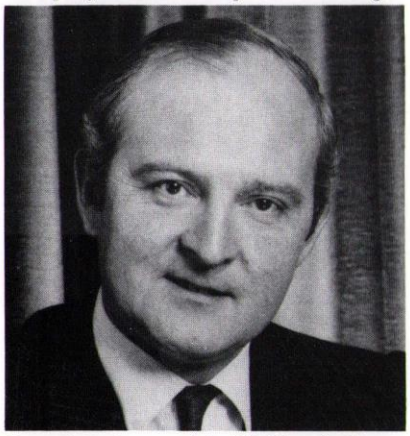


research include antennas, radar and fibre optics. He received the Rank Prize in opto-electronics in 1984 for his early work on optical fibre sensors. He is currently Chairman of the Assessment Committee for the Joint Opto-Electronics Research Scheme (JOERS) funded by both SERC and the Department of Trade and Industry.

Professor Fender, who is the new Chairman of the Science Board, was appointed Vice-Chancellor of Keele University in March 1985. This followed his three-year period as Director of the Institut Laue-Langevin in Grenoble, France, where he was Assistant Director from 1980 to 1982 and on the ILL Scientific Council for three years before that. After gaining his PhD from Imperial College, London in 1959, Brian Fender worked at the University of Washington, Seattle, and at the National Chemical Laboratory. He joined the Department of Inorganic Chemistry at Oxford in 1963, where he was Lecturer from 1965 to 1984 and a Fellow of St Catherine's College. He has been a member of the Science Board (1974-1977),

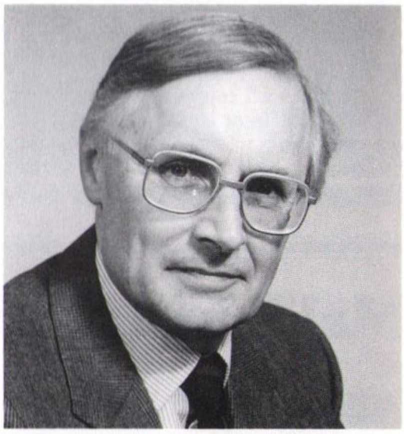
Chairman of the Neutron Beam Research Committee (1974-77) and of the Science Planning Group for the Rutherford Laboratory neutron scattering source (1977-80).

Robert Horton is a Managing Director of the British Petroleum Company plc with responsibility for finance and planning. He also has responsibility for the Group's activities in the Western Hemisphere and is on the Boards of SOHIO, BP North America and BP Canada. He has been General Manager of the BP Tanker Company and BP's Corporate Planning



Department, moved to BP Chemicals International in 1979 and was Managing Director and Chief Executive from 1980 to 1983. Mr Horton is a past President of the Chemical Industries Association, a Vice Chairman of the British Institute of Management, Chairman of the Council of Industry for Management Education and a Deputy Chairman of the CBI Economic and Financial Policy Committee.

Professor Jeeves has been Vice-Principal of St Andrews University since 1981. Having gained his PhD in Natural Sciences at Cambridge, Malcolm Jeeves continued with postgraduate work at Harvard. Before his appointment as Foundation



Professor of Psychology at St Andrews in 1969, he spent ten years as Foundation Professor of Psychology at Adelaide University in Australia. His major research interests are in neuro-psychology, especially problems concerning neural plasticity, and in cognitive science. He represents the UK and the Netherlands on the Committee of the International Neuropsychological Symposium. He has served on the Biological Sciences Committee and the Education and Training Panel of SERC and has been SERC's representative on the Royal Society's International Exchanges Committee.

Professor Perkins, who is the new Chairman of the Nuclear Physics Board, is

Professor of Elementary Particle Physics at Oxford University, a post he has held since 1965. After gaining his PhD at Imperial College, London in 1949 and three years as an 1851 Scholar, Donald Perkins spent some years at the Universities of Bristol and California before his appointment at Oxford. His work in neutrino physics in Gargamelle and the Big European Bubble Chamber at CERN gained him the Guthrie Medal and Prize of the Institute of Physics in 1979; his *Introduction to High Energy Physics* has become a standard text. During the past few years he has worked on proton decay experiments (Soudan 2) and is Chairman of CERN's Scientific Policy Committee. He was a member of SERC's Particle Physics Committee (1982-84) and the DESY Scientific Council (1982-85).

Dr Charles Reece has been ICI's Director of Research and Technology since 1979. He joined ICI in 1949 as a research

chemist, with a PhD from Leeds University and moved up through the company. In 1967 he transferred to the Mond Division, where he became Director (Research and Development) in 1969 and Deputy Chairman in 1972, moving in 1975 to the Plant Protection Division as Chairman. He is a member of the Advisory Council for Applied Research and Development and the Council of the Royal Society of Chemistry, of which he is a Fellow.

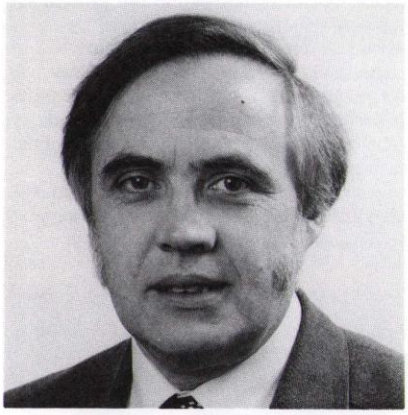
David Shore, who is the new Chairman of

the Engineering Board, is Technical Director of APV Holdings plc. He served a full engineering apprenticeship and has had some 40 years' experience in the design and manufacture of heat transfer equipment related to the food and chemical industries, especially in plate heat exchangers, evaporators, driers and distillation equipment. Mr Shore has been a member of the Engineering Board (1980-83), the Engineering Processes Committee (1979-80) and the Biotechnology Management Committee (1982-83). He is the current Chairman of the British Food Manufacturers' Research Association, is a member of the Council of the Fellowship of Engineering and the Process Plant Association and is a former Vice-President of the Institution of Chemical Engineers.

Professor Wilson has been the Perren Professor of Astronomy at University College London since 1972. He is Chairman of the National Committee for Space Research and Vice-President of the International Astronomical Union. He joined Harwell in 1959 to build up a plasma spectroscopy group, after a period in optical astronomy at the Royal Observatory, Edinburgh and in Canada.

He was appointed head of the Spectroscopy Division when Culham Laboratory was set up and extended its research into space astronomy with rockets and satellites. In 1968 he became Director of an independent Astrophysics Research Unit within the (then) Science Research Council, and worked on the development of the satellite ultimately adopted by NASA, the European Space Agency and SRC, the International Ultraviolet Explorer. He is a member of SERC's Astronomy, Space and Radio Board.

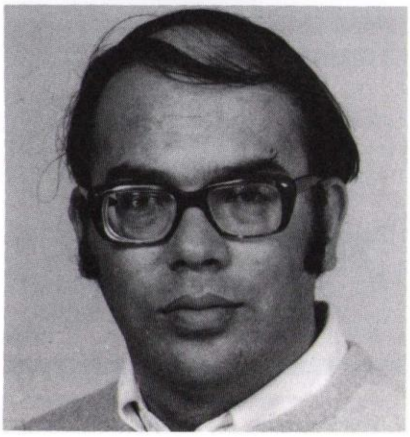
Low Dimensional Structures Coordinator



Professor John Beeby, Professor of Theoretical Physics at Leicester University, has been appointed Coordinator of SERC's new programme on Low Dimensional Structures (LDS), from 1 September 1985. Well known for his research in several fields of condensed matter physics, Professor Beeby has advocated a major programme of research and training in LDS, which represents a major new scientific development (see SERC Bulletin Vol 2 No. 12, Autumn 1984). He has been acting Coordinator of the programme since December 1984 and has been a member of SERC's Physics Committee and the Semiconductor and Surface Physics Subcommittee.

New head of Science Division

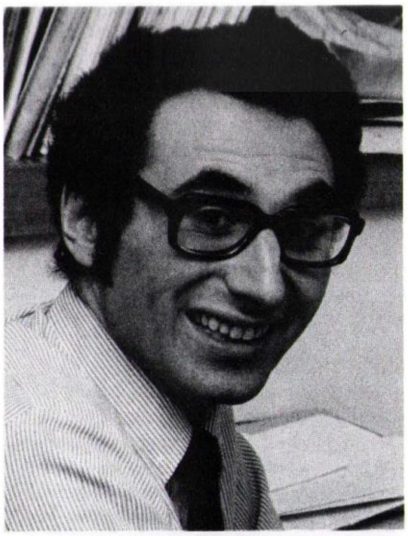
The new head of SERC's Science division, based at Central Office, Swindon is **Dr David Clark**. He replaces Dr Leo Hobbis, who has retired from the Council, and is returning to his native New Zealand. David Clark, also a New Zealander, has worked in the UK since 1971, at University College London, at the Royal Greenwich Observatory, and most recently as the Head of the Astrophysics Group at Rutherford Appleton Laboratory. His research background is in geophysics and astrophysics, using ground-based and space observations, and various historical topics in astronomy.



Plans for protein engineering

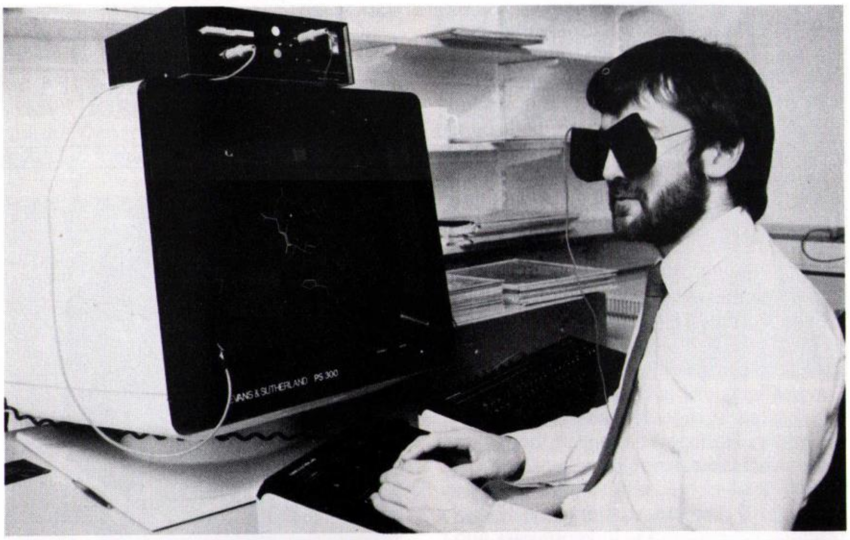
The Biotechnology Directorate recently concluded agreements with a number of companies to cofund a major programme of research in protein engineering in UK universities. The companies concerned — Celltech, Glaxo, ICI and RTZ Chemicals/J & E Sturge Ltd — will together, as a 'club', provide some £0.5 million towards a £2 million programme for research in protein engineering, the new science of manipulating genes to produce novel proteins unseen in Nature. Through protein engineering, it should be possible to produce new drugs, hormones and industrial enzymes better suited than the natural proteins as pharmaceuticals or industrial catalysts.

The aim of protein engineering is to use the recent, but now established, techniques of genetic manipulation to make proteins analogous to natural proteins but specifically altered in structure, and hence improved in function. Thus, in principle, one might produce a simpler or more stable analogue of a hormone, or an enzyme for industrial use which was more specific and more heat-stable than existing enzymes. To achieve such aims the protein engineer needs to know the detailed structure of the target protein, how that structure determines its function and, if possible, some rules as to how specific changes (such as amino acid substititions) will affect structure and function. The grants awarded by the programme to groups at Bristol, Leeds, Oxford, Sheffield and York Universities, Birkbeck College and Imperial College of Science and Technology are all directed towards meeting these needs.



Dr Robert Freedman, Programme Manager of the Protein Engineering Club.

As part of the programme, a substantial joint project, costing some £600,000, will be carried out by multidisciplinary groups at Birkbeck and Leeds on the prediction of protein structure. A major problem at the moment is that, while it is comparatively easy to discover the amino acid sequence of a protein by sequencing cDNA, it is much harder to determine the protein's tertiary structure — its detailed arrangement in space. To do this experimentally requires lengthy Xray diffraction studies on crystals of the pure protein, and for many proteins crystals are hard to obtain. The Birkbeck and Leeds groups will therefore be developing methods aimed at *predicting* the tertiary structure of a protein from its primary structure. The Leeds group, led by Professor Tony North, will concentrate on establishing a database to improve the prediction of secondary structure from primary structure; that is, to make it easier to recognise which stretches of amino acid backbone will fold into α helices or into regions of β sheets. The Birkbeck group, led by Professor Tom Blundell, already noted for their subtle analyses of patterns in the detailed internal architecture of proteins, will extend this work by constructing a database of tertiary structure, from which various structural motifs should be recognisable. Both groups will make considerable use of computer molecular graphics to represent and manipulate protein structures.



A researcher tries out new 3-D spectacles, part of the unique stereovision system developed at Leeds University for viewing complex protein molecules on the computer screen.

In addition to this work on the prediction of protein structure, the programme will be supporting work under Professor David Blow of Imperial College and Professor Pauline Harrison of Sheffield University, aimed at improving the whole methodology of protein crystallisation. Obtaining satisfactory crystals is one of the most time-consuming and least predictable aspect of determining a protein's structure by Xray crystallography, and improvements here would be a significant advance.

Other projects funded by the programme relate to specific proteins rather than to general methods. Some funds will go to studies on commercially interesting enzymes and proteins whose structures are not yet known in detail; these include enzymes involved in antibiotic production, in biological cleaning agents, and in the manufacture of sweeteners. Work on these topics will be carried out by Professor Guy Dodson's group at York, Professor North and Dr John Woodward of Leeds, and Professors Brian Hartley, Alan Fersht and David Blow of Imperial College.

However, simply knowing the structure of a protein will not necessarily make it easy to design improvements in function. What will be needed is a significant body of 'case law' experience drawn from making changes in a range of well-understood proteins and analysing the consequences of these changes. Ideally, such a body of experience might lead to a set of empirical rules for predicting the effects of any particular change. As a first step in this direction, the programme is funding projects to study some such 'model' proteins and the relation of structure to function. At Bristol University, Dr Herman Watson and colleagues will study phosphoglycerate kinases from yeasts, mammals and thermophilic bacteria and will engineer changes in the proteins to test theories about the factors contributing to heat stability in enzymes. At Imperial College, Professors Fersht and Hartley will study serine proteases and attempt to make planned changes in their specificity and other enzymic properties. At Oxford, a group led by Sir David Phillips will study the factors contributing to the specificity of antibodies.

All these projects will produce results which, in the long term, may be exploited to generate new processes and products. But some results from the programme may be commercially exploitable on a shorter time-scale. Ownership of products and processes will be assigned to the British Technology Group. However 'club' members will receive licences at a privileged rate and on an exclusive basis for an appropriate period of time. Net income generated by the programme will be shared between the companies, the universities and the British Technology Group.

The development of the programme will be under the supervision of a Steering Group, chaired by Dr Alan Williamson of Glaxo, and on which the participating companies, the academic community and SERC are represented. The university groups funded under the programme will report to the Steering Group at six-monthly intervals. In addition one of the authors (Freedman) has been appointed Programme Manager and will liaise closely with all the parties and coordinate research activity.

In June 1985 the final decisions were taken on the package of research projects to be funded under the first phase of the programme involving expenditure of some £1.3 million. Over the next 12 months further projects at universities will be supported and the participation of other companies in the programme will be encouraged.

The Biological Sciences Committee is contributing some funds to support this programme, but it has also seen the need to support more fundamental work in protein engineering to underpin commercial interests. Following a call for proposals earlier this year, the Biological Sciences Committee has now committed some £900,000 to the support of fundamental research in the area.

Dr Robert Freedman
Kent University

Dr Doug Yarrow
SERC Biotechnology Directorate

Projects supported under Phase I of the Protein Engineering Club

Location	Subject	
Birkbeck College	structure prediction)	collaborative
Leeds University	structure prediction)	
	methanol oxidase	
Bristol University	heat stability in enzymes	
Oxford University	antibody engineering	
York University	enzymes involved in antibiotic production	
Imperial College	subtilisin, glucose isomerase	
	studies of crystallisation)	collaborative
Sheffield University	studies of crystallisation)	

Spinks Studentships

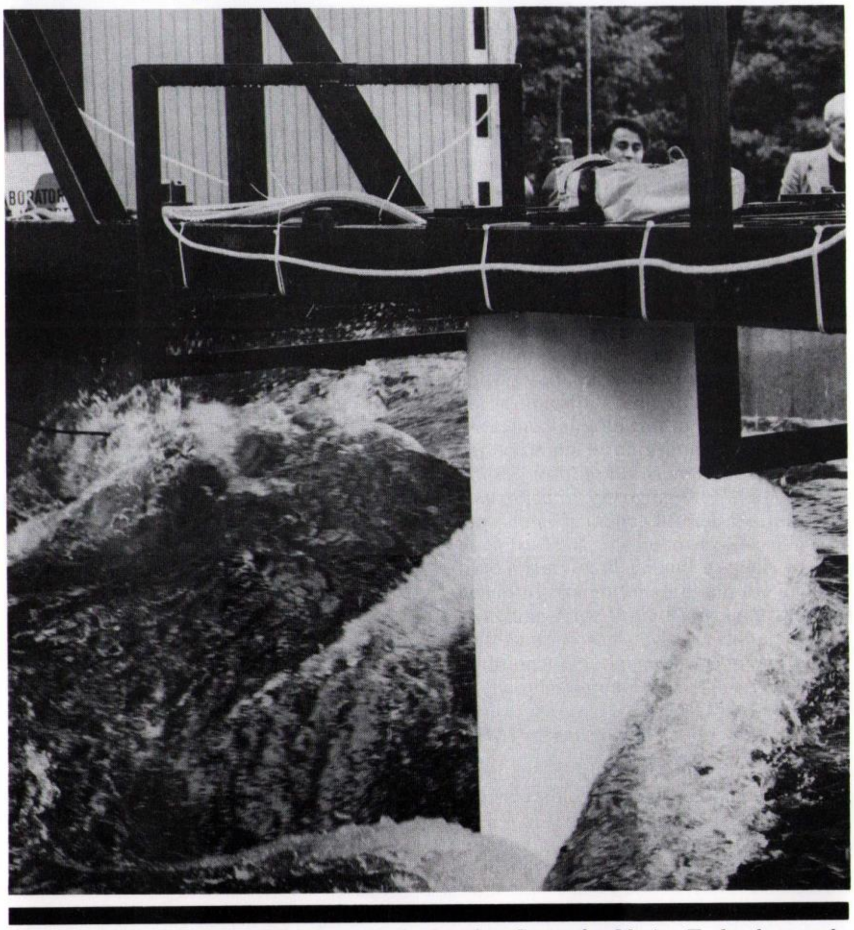
Mr Ken Edwards, Deputy Director-General of the Confederation of British Industry (right) and Dr John Ingham of Bradford University (next to him) meeting some of the students shortlisted for Spinks Studentships. This scheme was launched by the Biotechnology Directorate earlier this year (see **SERC Bulletin** ***Vol 3 No 2, June 1985) to encourage top quality engineering graduates to pursue postgraduate research in process engineering as applied to biotechnology. The response to the scheme was good and four three-year projects are due to begin in October. These involve the Departments of Chemical Engineering at Birmingham University, Bradford University and University College London, in collaboration with Celltech Ltd, ICI plc and John Brown Engineers and Constructors Ltd.***

The studies on which the selected students will be working cover the extrusion of cell pastes for enzyme immobilisation, shear and turbulence effects on microorganism behaviour, process design for use of temperature sensitive microbes, and the design of biocatalytic reactors.

Offshore development links universities and industry

After little more than seven years of SERC support and active development through a directed programme of research, the level of university expertise in marine technology research and development has grown from virtually nothing to a level where it is now possible to provide considerable support for industry in disciplines relevant to the complex technological problems associated with development of offshore resources.

Since it was set up by SERC in 1977, the Marine Technology Directorate has worked to develop, in the universities and polytechnics, a coordinated programme of research and training in marine technology which would attract industrial support and enable the academic community to assume its proper national role in the developing use of the oceans. Through the establishment of seven centres of marine technology research, the activities within the various engineering departments of a research institution and related activities of other universities and polytechnics could be coordinated nationally on a discipline basis; and thereby the means of collaboration between academic institutions, industry and government departments. This approach has proved successful: the research programme for 1985-87, which was compiled to emphasise management requirements and involvement of industry to meet the national needs, has attracted an investment of about £5 million from industry and Government, representing about 45% of the total programme cost. About 75% of the 1985-87 programme will consist of 14 managed programmes, each of which is composed of a set of interdependent projects which are coordinated towards meeting a common overall aim or set of aims. The remaining 25% of the two-year programme will consist of some 60 individual research projects. The diagram on the right shows the apportionment of funding to each of the managed programmes.



Fluid loading: In a joint project between the London Centre for Marine Technology and Marinetech North West, large-scale tests are undertaken at the Delft-Hydraulics Laboratory flume at De Voorst in the Netherlands.

The managed programmes

The managed programmes include a range of disciplines which will be important components in the future development of the UK offshore energy reserves and will have applications for the offshore industry worldwide.

Structural integrity monitoring offshore
The aim is to help industry develop improved underwater non-destructive testing and remote continuous monitoring systems to provide more efficient and more economic structural integrity monitoring offshore. Particular emphasis will be placed on improving existing techniques for location, sizing and monitoring of fatigue cracks, optical fibres and ultrasonic pulsed arrays.

Fatigue
To provide further understanding of crack growth behaviour in the range of steels used for welded and cast nodes, tethers, pipelines etc in air and corrosive environments. To develop fatigue life calculation procedures using the stress/life approach and spot stress based on fracture mechanics analysis and incorporating the effects of size, residual stress, remaining life, corrosion fatigue, variable amplitude etc and to extend these methods to new concepts such as cast and extruded nodes or tether connectors.

Defect assessment
To provide improved guidance for defect assessment and the derivation of defect assessment levels in applications relevant to offshore structural systems. In particular the following topics will be studied: heat-affected zone toughness, ultimate failure of tubular connections, interaction of damage and fatigue failure, reliability of defects, application of high strength steels and three-dimensional stress analysis.

Influences of welding on materials performance
To develop a greater understanding of the effect of welding on the properties of materials and their resulting performance in service. Emphasis will be placed on materials likely to be used by offshore industry in the future, such as high strength micro-alloyed steels, and corrosion-resistant alloys. The effect of welding on fractures, fatigue performance and corrosion behaviour will be studied.

Dynamics of compliant systems
To meet perceived industrial needs for design data on the overall dynamics of compliant systems, with emphasis on semisubmersibles and tension leg platforms, tanker/loading buoy systems, flexible hoses and risers leading to more cost-effective designs.

Fluid loading
Computational fluid dynamics methods will be developed to predict flows relevant to the offshore industry. Further work will be undertaken on loading and dynamic response of fixed horizontal and vertical cylinders with application to fatigue assessment.

Concrete offshore in the nineties
To develop competitive structures for home and overseas markets by:

- overcoming problems of material durability, non-destructive evaluation and repair;
- evolving techniques for more efficient use of structural behaviour;
- simplification of construction techniques.

Automation of subsea tasks
The research is directed towards improving the reliability and efficiency of subsea working and inspection systems while reducing the demands on personnel underwater and on the surface. The main objectives are to improve man-machine interface, increase safety aspects, reduce specialist personnel involvement, extend automated systems, increase the work rate at reduced cost and perform tasks in deeper water or more hazardous conditions.

Overall system design and management
The overall aim is to provide comprehensive conceptual design development and appraisal methodology for the extraction of hydrocarbon resources from undersea reservoirs. The methodology will be oriented to deeper water but also to marginal fields in general.

Integration of design technique for offshore structures
An overall structural design system for fixed and floating offshore structures will be produced, based on an 'expert' computer system and complemented by appropriate data bases.

Grouts and grouting for construction and repair of offshore structures
To widen the application of existing grout mixes and grouting techniques to the repair and strengthening of existing jacket platforms and pile fixing for deep water compliant systems.

Wire rope
To acquire a detailed understanding of the mechanical response of wire ropes in offshore applications and thereby provide a greater degree of confidence in the calculation of safety margins and endurance at all stages of lifetime.

Abandonment of offshore structures
The overall aims are to define appropriate developments for research associated with decommissioning, abandonment and dismantling of structures, where technological development is a prerequisite or where such development leads to major cost-saving, and to conduct pilot research necessary for proper definition and costing.

Performance-related efficient semisubmersible stability
The programme aims at a better understanding of factors affecting the performance of a semisubmersible particularly in the listed state. The results will be in the form of methods of assessment and computer software to predict behaviour in seaways.

SERC Marine Technology Centres

Cranfield Institute of Science and Technology

Glasgow University

Heriot-Watt University

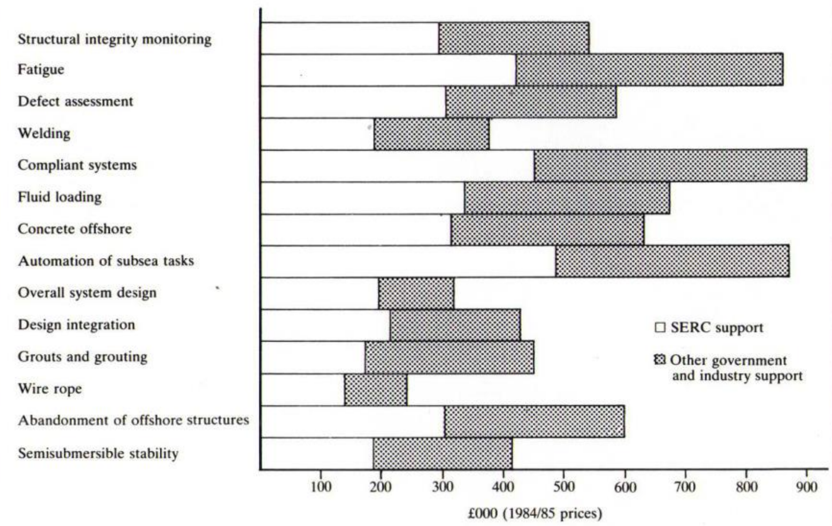
London Centre (comprising Imperial College of Science and Technology and University College London)

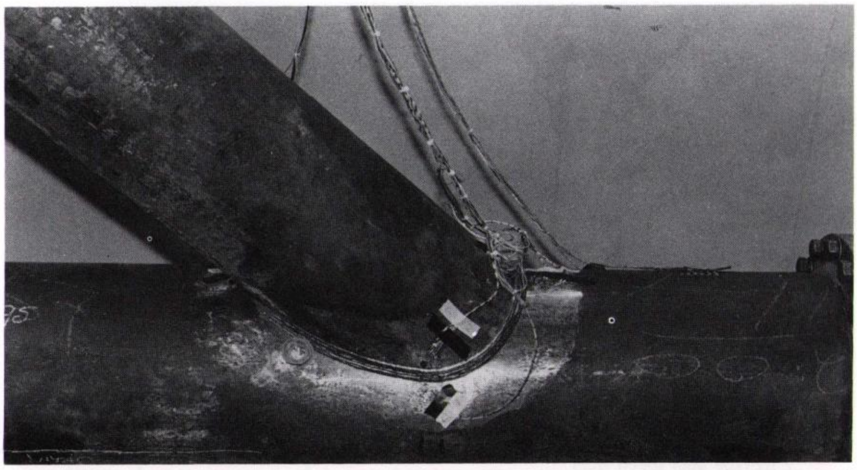
Newcastle University

Marinetech North West (comprising Liverpool, Manchester and Salford Universities, University of Manchester Institute of Science and Technology, and University College of North Wales, Bangor)

Strathclyde University

Support for managed programmes





Fatigue test rig for structural integrity monitoring at Cranfield Institute of Technology.

Research in powder processing

The joint SERC/Department of Trade and Industry programme in powder processing is an excellent example of SERC's policy for bringing the academic and industrial sectors together in research and development on applied problems of national importance.

The manufacture of components from metal or ceramic powder by consolidation under pressure followed by heating to a temperature at which the particles lose their identity (sintering) involves a specialised technology, much of which has evolved empirically. The process has the capability of producing complex shapes to high dimensional accuracy with optimum utilisation of material and energy. There is considerable flexibility in the composition of the materials which can be used, apart from the high-melting-point refractory metals and ceramics. Thus, the technology embraces unique products such as metal and non-metal composites, metal components of controlled porosity for filters and self-lubricating bearings, sintered carbides for machine tools and wear-resisting parts, and combinations of high- and low-melting-point metals for electrical contacts. The process is also well established for the large-scale manufacture of complex-shaped components in steel, soft iron, bronze and aluminium, where net shape forming results in a relatively low-cost production, with high material utilisation. In recent years, the use of the technology has been extended to high temperature materials for aero-engines and reciprocating engines and the process is currently being applied in research studies on rapidly solidified metal powders.

The SERC/DTI joint initiative

In the UK, the growth of the powder processing industry for the manufacture of engineering components has been slow compared with the industry in certain European countries, the USA and Japan. This has been due to the inability of the relatively small manufacturing units to support the research and development required and the lack of academic-industrial collaboration. During the early 1980s, the Department of Industry (now the Department of Trade and Industry, DTI) and SERC's Materials Committee recognised the growing importance of powder processing technology. In February 1982, the author was appointed as the part-time SERC/DTI coordinator to encourage the development of collaborative projects between industry and academics aimed at overcoming the technical and economic barriers to a more extensive exploitation of the technology in the UK. The Materials Committee recognised the need to transfer the technology across different materials sectors and that a total research and development programme should include powder metallurgy, engineering ceramics and solid-phase compacted polymers. Earlier this year, the Collyear Report (commissioned by the DTI) included engineering ceramics, rapid solidification technology and powder metallurgy in its recommendations for collaborative R & D and industrial exploitation in the field of new and improved materials and processes, and this underlined the coordination work already in hand.

Strategy and priorities

The coordination work has involved stimulation of academic studies in response to DTI and industrial requirements, and also of research and development in government laboratories and in industry in the context of the DTI strategy. Collaborative projects have been promoted through SERC and DTI funding schemes and inter-disciplinary and inter-university cooperation has been encouraged. Good relationships have been established with relevant organisations and government bodies including Ministry of Defence, British Technology Group and research establishments and with the various sectors of the manufacturing and user industries.

The first objective has been to establish effective collaboration between academics and the powder metallurgy industry through research studies in the major problem areas. Studies on most of the first priority academic topics are now in progress.

Coordination work on special ceramics has progressed more slowly although several research studies are currently being supported. Two consortia, supported by DTI, are concerned with the use of ceramics in gas turbine engines and in reciprocating engines, but there remains a need to improve coordination generally between academic and industrial R & D on problems in the industry. The situation is expected to improve as a result of a recent workshop on the subject.

Programme development

Currently, 27 projects to a total value of £1,107,000 have been funded by the Materials Committee since the launching of the programme in 1982. Cooperation with the trade associations covering sintered engineering components and hard metal products has resulted in useful and continuing dialogue between the academic community and industry.

Assisted by a workshop held in October 1983, most of the priority topics on sintered engineering components are now covered by academic research studies. A similar stage has been reached on priority problems in the sintered hard metal industry. Sintered high speed steels have

Priority areas for academic research

Sintered engineering components

- methods of updating component performance from the levels currently achievable with a single compaction/sintering route
- the scientific aspects of the lubrication of the compaction process
- quantification of rolling contact fatigue performance of sintered ferrous materials
- joining processes, concerned with properties, integrity and reproducibility in multicomponent assemblies

Hard materials

- new hard materials such as carbides, borides and other ceramics
- new coating techniques for hard metals and high speed steel components

High speed steel

- new compositions particularly suited to powder metallurgy manufacture
- metal cutting performance of T- and M-type high speed steel

Rapidly solidified powders

- optimisation of gas atomisation process, and safe powder handling procedures
- characterisation of alloy powders and their correlation with properties of the consolidated material
- studies of consolidation techniques which retain micro structural features, particularly in aluminium alloys
- design of alloys suited to the powder manufacturing route

Spray metal coatings

- development of innovative processes such as spray coatings, deposition and forging
- structure/property relationships of deposits and composites produced by spraying

Superconductors

- novel techniques for improved manufacture of niobium-tin superconductors using the powder route also featured in the programme and certain of the research grants have interacted with a Teaching Company project involving a manufacturer of high speed steel powder, departments at two universities and a research association.

In the field of rapidly solidified powders, a discussion meeting held in November 1983 established useful coordination of interests between two universities supported by research grants and representatives of Ministry of Defence establishments, British Aerospace and industry. As a consequence of that meeting, universities were invited to submit proposals for a study of new methods for consolidating rapidly solidified aluminium alloy powders and this has led to the award of four grants for feasibility studies.

The powder programme has stimulated applications for CASE studentships in the subject and currently approval has been given to 19 such projects. Close collaboration has been established with the SERC Specially Promoted Programme in Particulate Technology (see *SERC Bulletin* Vol 2 No 9, Autumn 1983). This has led to a project to study the granulation of tungsten carbide powders being accepted within that programme.

The industry-based projects within the coordinating work have involved a few single-client projects supported by the DTI. There has been, however, a rapid build-up of a wide-ranging portfolio of mainly multi-client projects at the BNF Metals Technology Centre, with financial support being provided by DTI Requirements Boards and SERC Cooperative Research Grants.

Exploitation

The many discussions during the past three years with the industry and trade associations have established a good climate for collaboration between the academic and industrial communities. In many cases, companies have expressed strong interest in approved projects and a desire to collaborate with the academic departments concerned. There have been applications for Cooperative Research Grants and several companies are contributing through the CASE scheme. Arrangements are in hand for a workshop to be held in October 1985 on the whole of the powder processing programme.

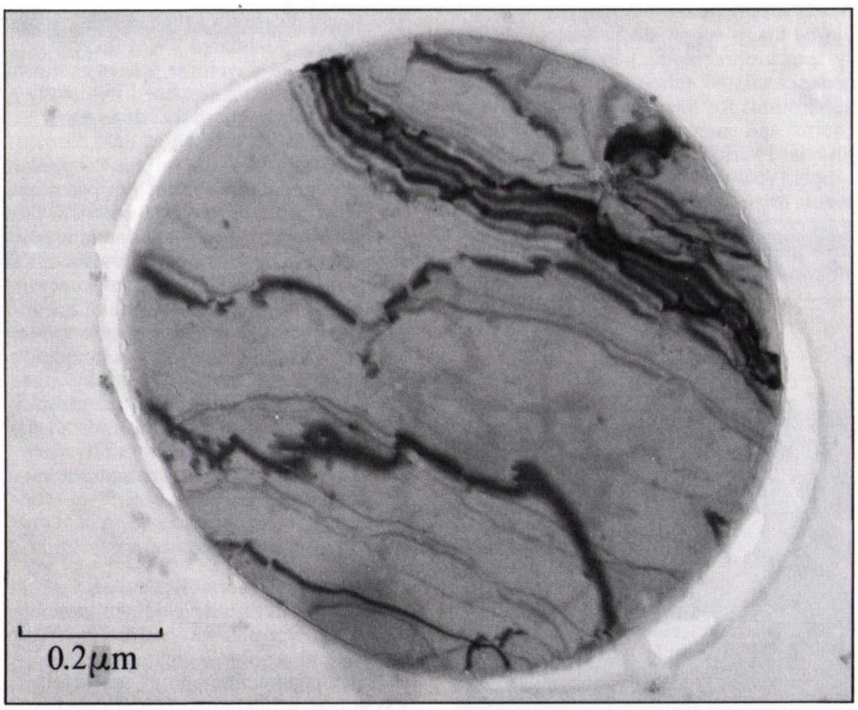
Further information on the powder processing programme can be obtained from the secretary, Dr S J Milsom at SERC Central Office, Swindon (ext 2338) or from the author, at Drift Cottage, Worthing, Dereham, Norfolk NR20 5HF; telephone Dereham (0362) 81601.

Dr Ivor Jenkins CBE, FEng
Powder Processing Coordinator

Awards made by SERC (1982-85)

Area	Number of awards	Amount of awards (£000)
Engineering components	8	204
Hard metals and high speed steel	4	123
Rapidly solidified powders	8	367
Ceramics	6	362
Polymers	1	51
Totals	**27**	**1107**

Sintered engineering components for the automotive industry (Photo: Manganese Bronze Ltd)



Transmission electron micrograph image showing segregation-free Al-Li alloy particle about 1 micron in diameter, produced by high pressure gas atomisation (Photo: Surrey University)

Switching industry to PWM power electronic control

Pulsed width modulation (PWM) power electronic control techniques are finding increasing application in UK industry. The techniques have been developed by a group in Bristol University's Electrical and Electronic Engineering Department which has acquired a high international reputation since it was set up in 1971, has received support from SERC and industry and collaborated with most of the major UK power electronic industries.

Power electronic control is the process of converting power from one voltage and frequency to a different voltage and frequency using some form of solid-state power switching converter. The voltages and frequencies involved may be discrete or continuously variable depending upon the application requirements. One such conversion process which is widely used in industry is based on the inverter, which transforms a dc voltage from either a battery or rectified mains supply into a variable-voltage, variable-frequency single- or three-phase ac supply.

There is a vast and increasing range of industrial applications for inverter-based systems, covering such diverse applications as uninterruptable power supplies (UPS), static frequency changers (SFC) and variable-speed drives (VSD).

Typically, UPS systems are used for interfacing computer-based data-processing systems, telecommunication systems, medical instrumentation, emergency lighting circuits etc to the mains power supply, to ensure integrity of supply during mains supply disturbances. SFC systems are increasingly in demand in commercial and military aircraft and naval applications for interfacing the auxiliary, control and computer equipment to the on-board variable-frequency finite power supply. VSD systems cover a wide range of motor drive applications, including traction, steel and paper mills, man-made fibre industry, machine tools, conveyors, air-conditioning, sheet-glass manufacture

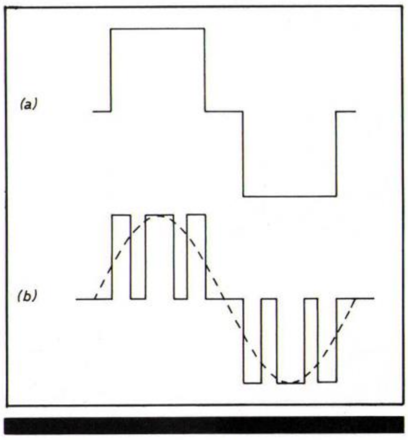


Figure 1. Inverter output voltage waveforms
(a) Quasi-square wave voltage
(b) PWM voltage

etc, including more recently applications in robotics.

PWM control techniques

In the past most inverter systems have operated in the so-called quasi-square wave mode, typically producing an inverter output voltage of the form shown in figure 1(a). This quasi-square wave voltage is produced by sequentially switching the load between the positive and negative polarities of the dc supply voltage using power electronic switching devices. The quasi-square wave voltage consists of a fundamental voltage plus harmonics voltages which cause harmonic losses and other detrimental effects in the load, and can significantly reduce system efficiency. In addition, fundamental voltage and power can only be controlled by changing the supply voltage which requires additional control equipment and complication.

These difficulties can be completely overcome using PWM inverter control techniques, as illustrated in figure 1(b). This figure illustrates a typical example of a sinusoidally modulated PWM inverter output voltage waveform, where as shown the widths of the pulses are sinusoidally modulated throughout a cycle of the fundamental. As a result of this modulation process the voltage harmonics, and consequently the harmonic power loss, are significantly reduced. In addition, the fundamental voltage can be continuously varied simply by adjusting the widths of the pulses, and the fundamental frequency controlled by changing the rate of sequential switching of the inverter power devices. Thus, the control of harmonics, fundamental voltage and frequency is all achieved straightforwardly in the inverter switching stage using PWM control of the solid-state power devices, without additional equipment and complication as in the quasi-square wave case.

PWM research at Bristol

Recognising the versatility and considerable future development potential of PWM systems, it was decided in 1971 to initiate and develop a comprehensive research programme into all aspects of PWM inverter systems. This research effort has produced new and significant results on the conceptional framework, analysis/design techniques, and operational modes of PWM systems.

The research activities at Bristol fall into two categories: fundamental long-term SERC-funded research, and more applied short-term design studies carried out in partnership with industry. The two activities are largely interdependent with the results of the long-term research feeding directly into the industrial design activities.

The research effort can be categorised in three areas, involving development of PWM switching strategies, computer-aided design (CAD), and microprocessor control.

Development of PWM switching strategies

Early research at Bristol into PWM inverter techniques identified and developed a new modulation process which was shown to have distinct advantages, both in operation and implementation, when compared with the earlier conventional PWM techniques. A simplified diagrammatic representation of the new PWM process is shown in figure 2, where a sinusoidal modulating wave (a) is sampled at regularly spaced intervals, corresponding to the peaks of the triangular carrier wave (b), to produce the sample-hold or amplitude-modulated wave (c). Comparison of the sample modulating wave (c) with the carrier wave (b) defines the points of intersection used to determine the switching instants of the width-modulated pulses (d). As a result of this process the widths of the pulses are proportional to the amplitude of the sinusoidal modulating wave (a) at regularly spaced intervals. The PWM pulses (d) are then used to control the power devices (thyristors, power transistors etc) in the inverter stage, which amplify the PWM control signal (d) to the required power level.

A significant feature of this process is the regularly spaced sampling times, which results in the widths and positions of the PWM pulses being precisely defined. This feature greatly simplifies the analysis and practical implementation of the technique, and results in improved performance of PWM inverter systems.

The process as described is referred to as regular-sample PWM and has been used as a basis for all subsequent research at Bristol, and also used as a basis for initiating new research throughout the world.

Microprocessor control

Developments in microprocessor control of power electronic systems, together with the emergence of new fast switching power electronic devices, GTOs, FETs, power transistors, and so on, offer enormous development potential. For example, the replacement of control hardware by microprocessor software, together with intelligence-based microprocessor fault-monitoring and diagnostic capabilities, should in the future reduce manufacturing cost, increase reliability and improve maintenance and servicing of power electronic equipment. It is therefore imperative, if UK industry is to compete successfully in international markets, that university research is directed towards assisting industry to take full advantage of these new technological developments.

In recognition of this, microprocessor-based power electronic control was first started at Bristol in 1975, initially using 8-bit microprocessors and more recently as 16-bit microprocessors became available these have been incorporated into the research programmes.

Since 1975 all the microprocessor techniques for implementing the various PWM inverter control strategies have been investigated, and the implications of the various microprocessor hardware/software design trade-offs identified in terms of their effects on microprocessor speed, accuracy and timings.

As a result of this research, new 'optimised' PWM microprocessor control techniques have been developed which minimise harmonic effects and significantly improve system performance. It is predicted that these optimised PWM techniques will be increasingly used by UK industry in the future.

Computer-aided design of power electronic systems

The increasing availability of digital computers now makes the computer-aided design (CAD) of power electronic systems a powerful and cost-effective development tool. This trend is likely to continue in the future as low cost powerful microcomputers become available, allowing system designers easy access to 'inhouse desk-top' computing power. To take full advantage of these low-cost computing facilities it is necessary to develop power-electronic CAD packages which can be mounted and operated within the microcomputer's capabilities.

A number of power electronic CAD packages have been developed over the years in Bristol, and these have been used extensively for both research and collaborative industrial design of UPS, SFC and VSD systems. In recognition of the power and design potential of these CAD facilities, recent publications have been awarded the Institution of Electrical Engineers' John Hopkinson Premium, and the Sebastian Z de Ferranti Premium.

To demonstrate the use of these packages for transient PWM VSD investigations, figure 3 illustrates the effects of switching directly from PWM to quasi-square wave operation. Figure 4 illustrates the corresponding experimental results obtained from a microprocessor controlled PWM VSD system. As demonstrated in these figures good correlation is possible, confirming the validity and accuracy of the modelling techniques used in the packages.

Future developments

As a result of the introduction of microprocessor-based control into power electronic systems, the possibility now exists of including 'intelligence-based' techniques to improve system performance, for example, fault-monitoring, self-interrogatory and diagnostic capabilities, remote control features, on-line parameter measurement, system identification, software-base modelling, and self-tuning adaptive control techniques.

Thus long-term research will be increasingly aimed at integrating all the new techniques/technologies into power electronic system design and development. This will involve an interdisciplinary team drawing on the specialised skills of other researchers in the department, including, in addition to power electronics, microelectronics, control, computing and communications.

Developing the academic-industrial interface

Bristol has for many years recognised that the key to successful power electronics research is to be actively involved with industry, both in terms of long-term research programmes and also short-term collaborative projects. Past experience at Bristol has shown that the interchange of ideas, identification and solution of problems, and the transfer of techniques and technology can only be successfully achieved by a process of close interactive collaboration. This can take various forms ranging from SERC/industry-supported CASE studentships and short-term collaborative projects, through to industry-funded design/development contracts and consultancy work. The time scales involved and nature of the work vary in each case depending on the funding arrangements and project targets.

Further details can be obtained from the author at:

Department of Electrical and Electronic Engineering, Queen's Building, University Walk, BRISTOL BS8 1TR. Telephone: 0272 24161 (ext 409).

Dr S R Bowes
Bristol University

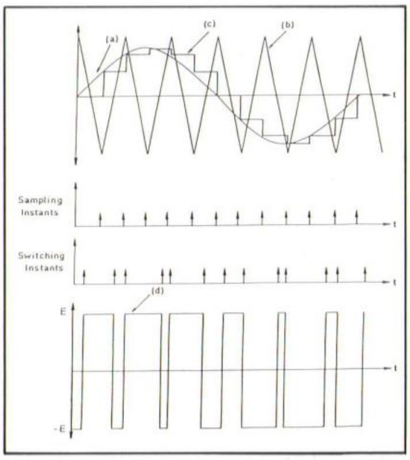


Figure 2. Regular-sampled PWM
(a) Sinusoidal modulating signal
(b) Carrier signal
(c) Sample-hold modulating signal
(d) PWM waveform

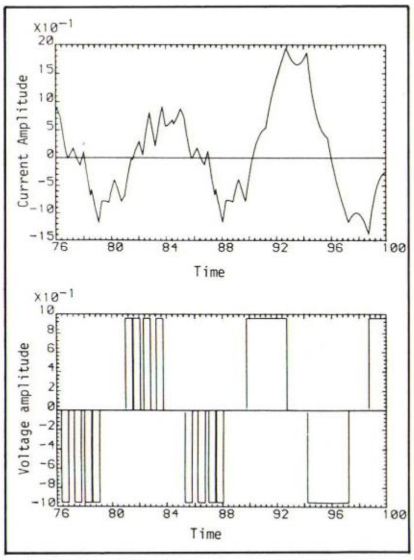


Figure 3. Computed results for switch from PWM to quasi-square wave.
Upper trace: current
Lower trace: voltage
NB All quantities are in per-unit

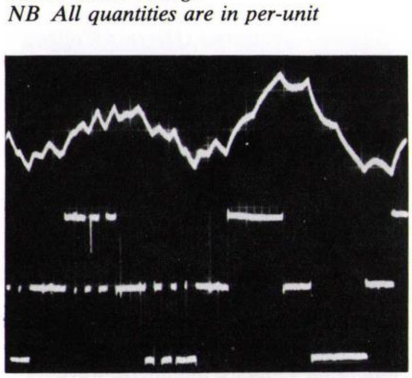


Figure 4. Experimental results corresponding to Figure 3.

Sir Harrie Massey — 1908-1983

In the spring of 1985, the Royal Society of London, the Australian Academy of Science and the Anglo-Australian Telescope Board sponsored a scientific symposium in Canberra to celebrate the many, far-reaching contributions which Sir Harrie Massey made to science throughout a long and very distinguished career. It was fitting that the symposium was held in a spirit of cooperation between Australia and the UK since Sir Harrie was an Anglo-Australian who contributed greatly to science in both countries.

Sir Harrie Massey was born in Hoddle's Creek, close to Melbourne, and among his earliest memories was being shown the 1910 apparition of Halley's comet by his father. His interest in science and astronomy at school in Melbourne was evident in the glowing reports of his lecture to the school Scientific Club recorded in the school magazine of Christmas 1924:

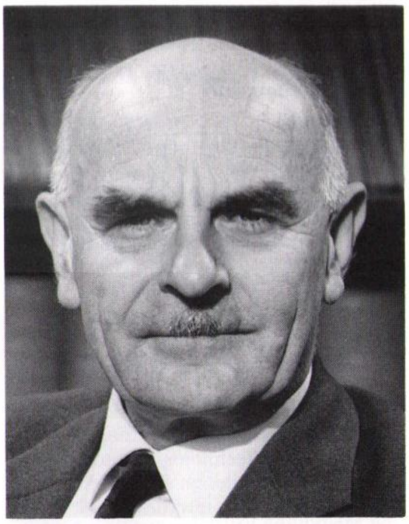
"A large number attended and were spirited away across the ether to distant planets and stars where the wonders and beauties of the sights were unfolded to them by the magic hand of Harrie Massey."

After an outstanding school and university career, he came to the UK in 1929 where he began his studies of the application of the quantum theory to collisions of atoms, ions and molecules. Even by this early date, many of the main themes which were to run through the rest of his career were crystallising. This was reflected in the title of the Massey Memorial Symposium, **Atoms and Molecules in Astronomy**.

The lectures were presented by scientists who had been associated with Sir Harrie in one way or another through his long career. Two points soon emerged. First, every speaker felt he was no more than scratching the surface of the huge contributions which Sir Harrie had made. Second, many of the most important growth areas of modern astronomy build directly or indirectly upon research or initiatives taken by him.

Two excellent examples of this second point were made by Professor K Takayanagi (Institute of Space and Astronomical Science, Tokyo) and Professor A Dalgarno (Harvard College Observatory) who described different aspects of the role of molecular collisions and chemical processes in astrophysics.

Professor Takayanagi showed how a number of complex collision processes of importance for astronomy are now well within the capabilities of detailed theoretical studies. These will be of particular relevance in interpreting the observations made with the new generations of millimetre and sub-millimetre telescopes such as the Nobeyama 45-metre millimetre-wave telescope and the UK-Netherlands millimetre-wave telescope which is nearing completion in Hawaii.



Sir Harrie Massey

Professor Dalgarno addressed the central problems of the relatively new discipline of interstellar chemistry. Recent studies have isolated the main processes of gas-phase chemistry which results in the formation and destruction of light molecules in giant molecular clouds. Of particular importance are those reactions which involve deuterium, since the abundance of deuterium in the interstellar gas is one of the key diagnostics of the early thermal history of the Universe. The chemistry of the clouds must be understood if the observed abundances of molecules containing deuterium are to be related to the primaeval abundance of deuterium. Dalgarno showed how the observed molecular and chemical abundances of deuterium are consistent with the predictions of the standard Hot Big Bang model of the early Universe.

Southern Hemisphere astronomy

One of Sir Harrie's major contributions was in supporting the development of major observing facilities for UK and Australian astronomers in the Southern Hemisphere. Because of his unique position in UK and Australian science, he was instrumental in obtaining approval for the Anglo-Australian Telescope (AAT), construction of which began in 1967. Sir Harrie was a long-standing member of the Anglo-Australian Telescope Board, the inter-governmental body which is ultimately responsible for the operation of the telescope. From 1980 to 1983 he was Chairman of the Board, and the new AAT laboratories and base facility in Epping, New South Wales, have been named the Massey Building in recognition of his contribution to the AAT and science in general.

Sir Harrie recognised the very great scientific potential of world-class observing facilities in the Southern Hemisphere. Most of our own Galaxy, and in particular the Galactic Centre, lies in the Southern Hemisphere. Our nearest neighbours in space, the Large and Small Magellanic Clouds, can only be observed in the South. From the point of view of the development of optical astronomy in the UK, the AAT and the UK Schmidt Telescope, which is located alongside it, have been the most important telescopes to which UK and Australian astronomers have had access.

Dr D C Morton (Director of the Anglo-Australian Observatory), described some of the remarkable new science which has been carried out with the AAT using atoms and molecules as diagnostic tools. Bessell and Norris have discovered the star with the lowest abundances of heavy elements yet known. Relative to the Sun, the abundances of iron and other heavy elements in the star CD $-38°$ 245 are depleted by a factor of about 30,000. The study of these extremely 'metal-deficient' stars is very important because they were formed out of material which had not been significantly enriched by the processes of stellar nucleosynthesis. Some metals are present with relative abundances roughly consistent with nuclear processing in massive stars and so presumably there must have been some processing of the primordial material even before this star formed.

Another remarkable discovery by Graham, Meikle, Allen, Longmore and Williams is of the large abundance of iron in a recent supernova in the galaxy M83. It is believed that the energy source for this type of supernova outburst (a type 1 supernova) is the collapse of a white dwarf due to the accretion of large amounts of matter on to its surface. In the nuclear reactions which occur during collapse, a large amount of radioactive nickel is synthesised, which decays into iron with a half life of 78 days. This may be the energy source for the exponential decay of the optical luminosity of the supernova as well as for the large quantities of iron observed about 350 days after the outburst. This is important evidence about the nature of the light curve of this type of supernova and for the processes of formation of the heavy elements.

Dr D K Aitken (RAAF Academy, Melbourne) described how atomic, ionic and molecular line studies in the infrared waveband have revolutionised the study of regions of star formation. Virtually all young stars seem to possess outflows of ionic and molecular material, in many cases involving a considerable mass. He also showed how huge molecular aggregates, or dust particles, can be particularly effectively studied in these wavebands. Perhaps the most intriguing new feature of his results was the interpretation of the polarisation properties of the dust absorption features observed in the infrared waveband. These may well prove to be a very delicate probe of the interaction between the dust particles and their environment.

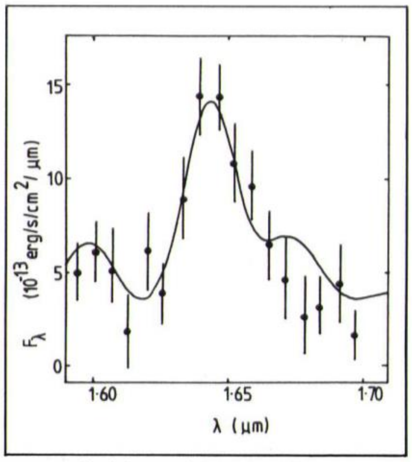
Moving out of our own Galaxy, Professor D A Mathewson (Director of the Mount Stromlo and Siding Spring Observatories) described the use of atomic hydrogen to probe the structure and interaction of the Magellanic Clouds with our Galaxy. Perhaps his most remarkable result was the proposal that the Small Magellanic Cloud is not one but two galaxies seen in projection on the sky.

The UK space programme

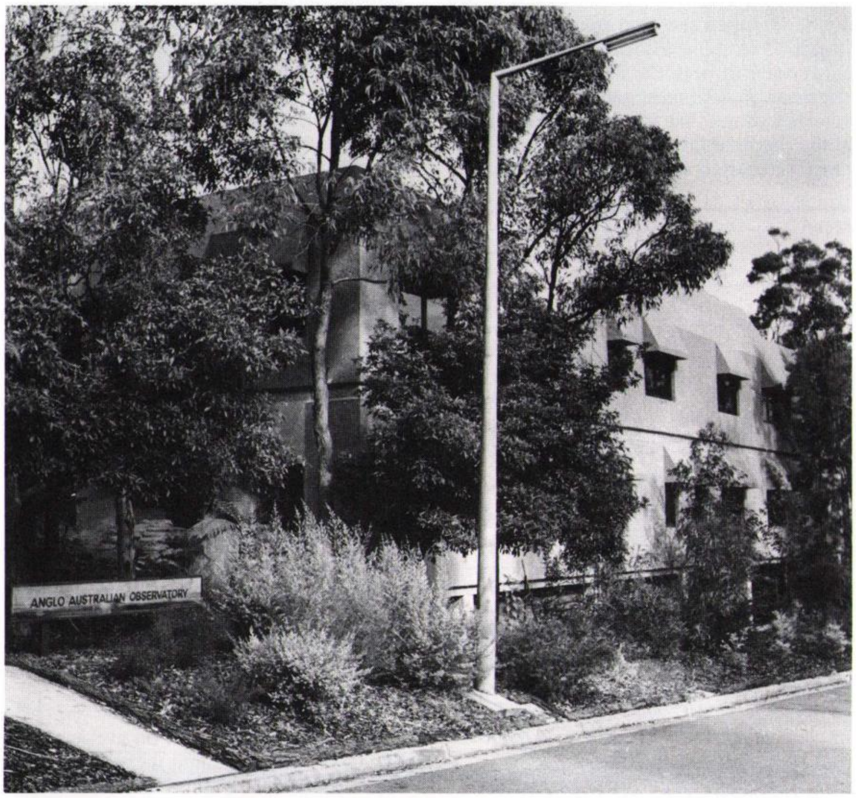
Sir Harrie was one of the founders of the UK space programme. The programme began with rocket studies of the upper atmosphere in 1953 and continued through the 1960s and 1970s with the Ariel series of satellites. His initiatives resulted in the development of the Mullard Space Science Laboratory of University College London. That group under Professor Sir Robert Boyd FRS and the Leicester Xray astronomy group under Professor Ken Pounds FRS established a world-wide reputation for the UK in the field of Xray astronomy. It was fitting that Professor Pounds described the central importance of Sir Harrie's contribution to UK space science. He showed how much had already been achieved in Xray astronomy and pointed out the significance of new space projects, particularly in the field of Xray spectroscopy. Developments in detector technology and the increase in the mass of payloads which can now be placed in orbit make it quite feasible to design Xray spectrometers of high sensitivity and high spectral resolution. These will open up many new areas of science, ranging from the detailed study of the accretion discs around white dwarfs, neutron stars and black holes to the gaseous content of clusters of galaxies and perhaps even to new astrophysical means of measuring the present rate of expansion of the Universe.

Even in this very brief review, the enormous range of Sir Harrie's interest and enthusiasm will be apparent and only a few of the many topics in which his influence was felt have been mentioned. His scientific achievements and his contributions to the development of science policy in the UK, Europe and elsewhere are a matter of record (Biog Mem Fell R Soc, *30*, 445-511, 1984). But through it all, one is most impressed by his integrity and wisdom as a scientist and a thinker, whose prime concern was the advancement of science as a whole.

Professor M S Longair
Director, Royal Observatory, Edinburgh



The spectrum of singly-ionised iron in a recent supernova in the galaxy M83 observed in the infrared waveband by Drs J Graham, P Meikle, D Allen, A Longmore and P Williams with the AAT.



The Massey Building, in the grounds of CSIRO at Epping, NSW, is the scientific headquarters of the Anglo-Australian Observatory. It acts as a support facility and laboratory for astronomers and staff for operations of the Anglo-Australian Telescope.

The EISCAT incoher

The incoherent-scatter radar technique provides physicists stud with their most powerful ground-based instruments for the remo environment.

Following the development of powerful transmitters and sensitive receivers — required for the military exploitation of radar — the first echoes incoherently scattered by the ionosphere were received, in America, in the late 1950s. Subsequently, a small number of permanent facilities were set up, including two in Europe — in the UK and France. These instruments' proved to be very effective indeed and in 1975 an agreement was signed between the research councils of the UK, France, West Germany, Norway, Sweden and Finland to build a pair of powerful and sophisticated incoherent-scatter radars in the European auroral zone. These radars are run by the EISCAT (European Incoherent SCATter) Scientific Association and both are now available for scientific studies; one has been operational since late 1981 and the other is well into its testing period before routine operations begin.

A radar signal transmitted into the ionospheric plasma will be scattered by the electron population and can be received by a suitably sensitive receiver; in practical systems, megawatt transmitter pulses are associated with picowatt inputs to the radar receivers. The scattering mechanism is not truly incoherent since the radar wavelengths employed are large compared with the Debye shielding distance and consequently the observed electron behaviour is partially controlled by the much more massive ions. The characteristic double-humped received spectrum (figure 1) contains information about the parameters of both the ions and the electrons. A full investigation of the physics involved shows that accurate determination of the shape of this spectrum allows a wide range of ionised and neutral atmosphere parameters to be measured or deduced. The directly measurable parameters include the electron number density and temperature, the ion temperature and composition, the ion drift velocity (normally related directly to the ambient electric field) and the ion-neutral collision frequency. The derivable parameters include the neutral gas density and temperature, the neutral gas velocity, the electric current flow and the Hall and Pedersen conductivities.

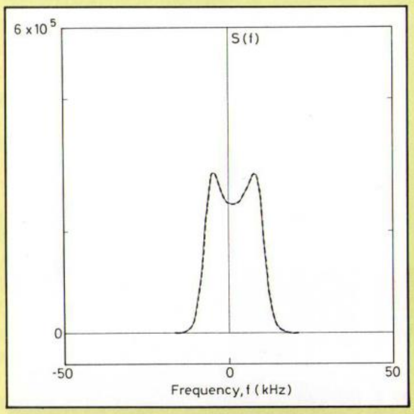


Figure 1: Characteristic double-humped 'ion-line' spectrum of the signal received by the UHF EISCAT radar. The dashed line shows a numerically-modelled synthetic spectrum and the solid line is the corresponding best-fit spectrum produced by the analysis procedures. From the known values of the plasma parameters used to synthesise the test spectrum, the accuracy of the analysis routines çan be assessed.

The two EISCAT radar systems complement each other, with each excelling in particular areas of study. The first to be brought into operation uses radio frequencies near 930 MHz with the transmitter and a receiver at Tromsö, Norway, and additional receivers at Kiruna, Sweden, and Sodankylä, Finland. The availability of three geographically separated receivers provides three independent estimates of the bulk plasma motion from which the three-dimensional velocity vector can be derived. This ultra-high frequency (UHF) system can study the plasma along the Tromsö beam direction in the approximate altitude range 90-900 km with additional full vector velocity information at one or more points determined by the intersection of the transmitter and remote receiver beams. In contrast, the second (VHF) radar operates near 244 MHz and has only one receiver, located with the transmitter at Tromsö. This system has a substantially higher peak power than the UHF radar (5 MW as opposed to 2 MW) and this, coupled with a large antenna and the ability to observe at lower plasma densities, will allow observations to be made at all altitudes between about 70 and several thousand kilometres.

Both systems are equipped with sophisticated computer control systems and can transmit and receive very complex radar pulse trains including the use of up to 16 frequencies, and mixed multi-pulse and long-pulse schemes. Additionally, phase reversal may be employed to allow some, or all, of the transmitter output to be Barker-coded to provide fine range resolution.

The radars are operated, on average, for two days each week and these operations are divided equally between 'common programmes' — regular observations of general interest designed for long-term studies — and 'special programmes'. In the latter, scientists from the associate countries can run detailed programmes of their own design aimed at furthering individual research projects.

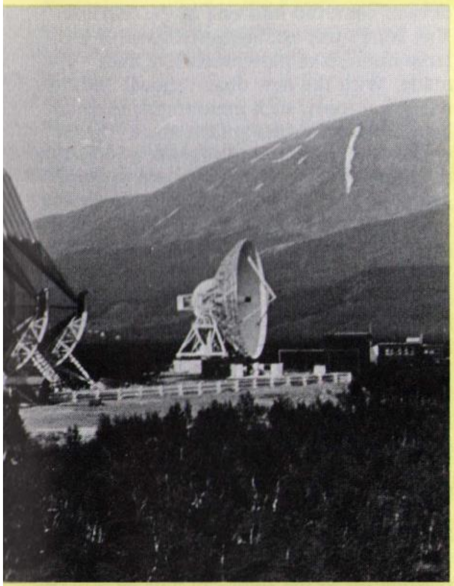
A general view of the EISCAT installations at dish is part of the UHF facility. Similar dishes metre parabolic-cylinder antenna is used for the to a limited degree, also in azimuth.

The system is heavily used by UK scientists, supported by a group at the Rutherford Appleton Laboratory (RAL), and experiments are normally grouped together into UK campaigns in order to optimise the use of resources. A database of common programme data is maintained on a UK EISCAT project computer at RAL. This machine has also been used to support remote monitoring of the radar, allowing scientists to conduct experiments with EISCAT without needing to leave the UK.

The topics studied by the UK community encompass most of the currently active areas of ionospheric research. This was recently demonstrated when the RAL EISCAT section, led by the UK EISCAT Project Scientist Dr D M Willis, assisted by several university groups, mounted a special display. Time constraints allowed the work of only a fraction of the UK EISCAT community to be included in the display, with representatives from Leicester and Ulster Universities, University College of Wales, Aberystwyth and Imperial College of Science and Technology being present. In addition,

ent scatter system

g the Earth's upper atmosphere, ionosphere and magnetosphere
observation of these important regions of the terrestrial



msö. The fully steerable paraboloidal 32 metre installed at the remote sites, while the 40×120 IF system. The latter is steerable in elevation and,

dramatic video recordings of an auroral substorm over EISCAT — a sudden brightening of the visible aurora — were shown using data from the all-sky cameras developed by the Universities of Southampton and Sussex. Substorm phenomena have also been studied by EISCAT in conjunction with the German IRM satellite of the AMPTE mission. The IRM was then in the geomagnetic tail where the Earth's magnetic field lines have been extended away from the sun by the action of the solar-wind outflow of ionised gas. It is in this region that magnetic-field-configuration effects and reconnection phenomena give rise to the energetic particle precipitations which, in turn, excite the optical emissions of the Earth's atmosphere in the auroral regions. The display included a colour graphics terminal that was used to plot data, as if in real time, from the UK Special Programme EASE (EISCAT-AMPTE Substorm Experiment), obtained using a radar program which is, in all likelihood, the most complex ever devised.

Other results on display showed comparisons of EISCAT data with results from the UK subsatellite (UKS) of AMPTE when in the solar wind. The solar wind carries with it a magnetic field of solar origin called the interplanetary magnetic field (IMF) which was monitored by the UKS. The solar wind, and the IMF embedded within it, generate large-scale 'convective' motions of plasma in the high-latitude ionosphere which are known to vary with the orientation of the IMF relative to the Earth's magnetic-field axis. By pointing the EISCAT UHF radar to the north, changes in plasma convection were observed following a swing of the IMF from northward to southward (see figure 2) — the delay in the response being measured accurately for the first time and being of great interest to the theory of the interaction of the solar wind with the Earth's magnetosphere. EISCAT data also show the effects of increased plasma convection on the ionosphere as ion temperatures are raised by frictional heating with the neutral atmosphere and plasma densities are depressed by enhanced plasma loss processes, giving high latitude trough phenomena.

There was much interest in the use of EISCAT as a diagnostic device to study man-made modifications of the ionospheric plasma produced using a high power, high frequency radio transmitter located adjacent to the EISCAT transmitters at Tromsö. Initial results reveal enhanced electron temperatures, produced as high frequency waves are resonantly scattered into Langmuir plasma waves, and as small-scale plasma irregularities form, aligned with the local geomagnetic field.

Also on display were comparisons with data from a Fabry-Perot interferometer and NASA's Dynamics Explorer satellites. These provided interesting new results on field-aligned plasma flows between the ionosphere and the magnetosphere and, in addition, observations of wave phenomena in the ionosphere due to magnetic pulsations and internal gravity-waves in the atmosphere.

The first four years of operation of the EISCAT UHF system have seen this, and other, exciting work carried out by UK scientists. Increasing system reliability and developments in the use of radar controller and correlator promise even greater returns in the near future. In addition, opportunities offered by the VHF system and collaborative research with spacecraft missions, such as Sweden's Viking, the European Space Agency's Cluster and NASA's Global Geospace Mission, mean that EISCAT will remain at the forefront of auroral-physics studies for a long time into the future.

A P van Eyken and M Lockwood
Rutherford Appleton Laboratory

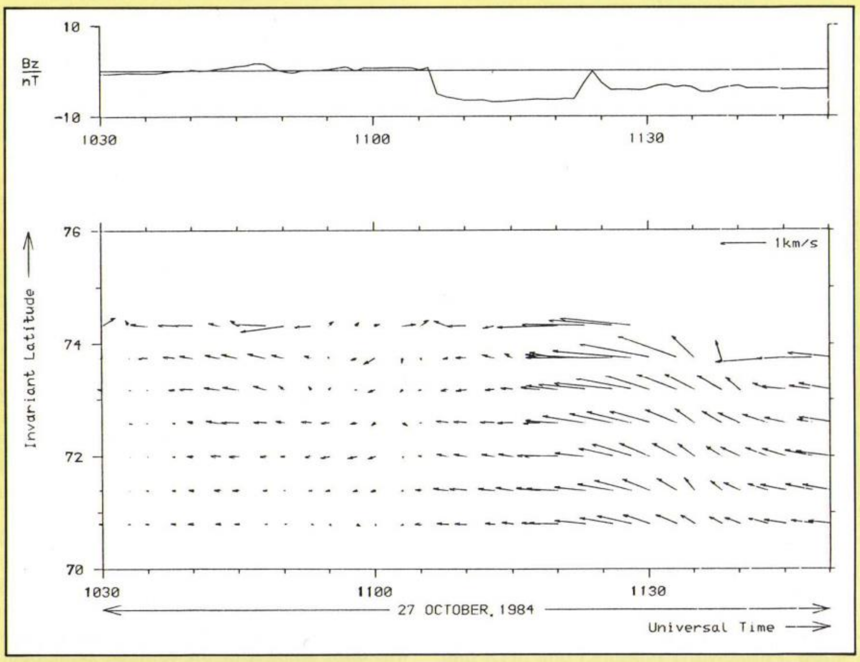


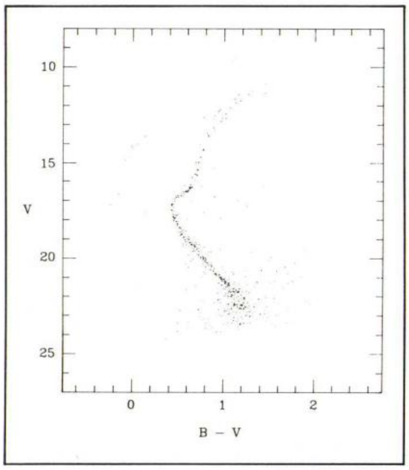
Figure 2: Comparison of plasma velocity vectors, seen in the high latitude ionosphere by EISCAT (lower panel), with the northward component of the interplanetary magnetic field (Bz), seen simultaneously by the UKS subsatellite of the AMPTE mission. The southward turning of the interplanetary field (Bz becomes negative) at 1106 UT is followed by a marked increase in the electric field and associated convective flows.

Determining the age of the Universe

The Universe is between 10 and 20 thousand million years old. It is a triumph of science that we can say this with some certainty but there is great interest in tying down the age more exactly. The new ideas of physics, which go under such exotic names as inflation, super-symmetry, superstrings, eleven-dimensional space-time, etc, make testable predictions about the structure of the Universe. Bringing together all the cosmological observations that can be made will give us a good picture of the evolution of the structure of the Universe from a very short time after the Big Bang right up to the present. This will test those predictions and push along the revolution in physics that is now happening.

The age of the Universe is one of these observations but, to be of use, we must know the age more accurately than we do now. An accuracy of 5 to 10% is desired, and anyone who deals with astronomy will know how ambitious this is. Even the simplest things — for example the distance to the nearest cluster of stars — are scarcely known to this accuracy. However, using new precision observational and theoretical tools, there has been distinct progress to this goal. The authors have recently made observations which make a significant step forward.

The method used was to date the oldest objects in the Universe whose ages can be found. As the Universe exploded from the Big Bang, the galaxies formed out of primeval chaos. The epoch of their formation can be seen by looking out into space (and thus backwards in time) to the point beyond which we do not see any more quasars. This point is found at 85% of the way back to the Big Bang. As quasars are found in the centre of galaxies, this suggests that the galaxies formed when the Universe was some 15% of its present age. When the galaxies formed, one of the very earliest things that happened was that in each galaxy a number of compact groups of stars were born, and these groups, known as globular clusters, separated themselves from the further evolution of their parent galaxies. In our own Galaxy, there are about a hundred of these clusters.



A plot of the brightness and colour of the measured stars in NGC6752. Brightness increases upwards and temperature (and blueness) increase to the left.

If we could find the ages of the stars in such a cluster, we would then have a good estimate of the age of our Galaxy and thus, with the addition of 15% from the quasar information, of the age of the Universe. So how can we find those ages? Well, when they are formed, the more massive stars burn their fuel quickly and are bright and hot (and thus look blue), while the low mass stars are faint and cool (and thus look red). As the hydrogen burns in their centres, it gets used up and, at a certain age, so much of this fuel has been consumed that the structure of the star changes. It quickly gets brighter and redder, the stars becoming 'red giants'. The bigger the star, the sooner this happens. So if we look at a globular cluster, some of the more massive stars in it will have changed from being bright and blue to become brighter and red, while the less massive stars will have remained faint.

Since stars are simple balls of gas, this means that we can now enter the physics of their structure into a computer program, calculate the burning of the hydrogen and determine at what age a star of given brightness and colour will undergo this sudden change. Looking at a real globular cluster, we can see at what brightness and colour it is now actually occurring and thus find the age of the cluster. Recent progress, both in the physics of the structure of stars and in computational power, has led to a major improvement in the accuracy of observation. For one of the nearest clusters — NGC6752 — very accurate measurements of the brightnesses and colours of the stars were made. This was done using imaging cameras equipped with solid-state, charge-coupled devices on the Anglo-Australian Telescope and on the South African Astronomical Observatory's 1-metre telescope. These cameras were built by the Royal Greenwich Observatory (on the AAT), and by University College London (on the SAAO 1-metre). Digital pictures of the clusters taken with these devices were fed into one of the Starlink Vax computers and measurements of a large number of individual stars were made. With the new observational and analytical tools, such measurements could be made for extremely faint stars. These results are plotted in the figure, a plot of brightness against colour. This 'colour-magnitude' diagram clearly shows the unevolved faint red stars and slightly brighter bluer stars lying on a line (the 'main sequence') from top left to bottom right. It also shows that the brightest stars are no longer on the top part of this line, but have moved over to the right and become red giants. (There are a few bright hot blue stars which have evolved beyond the red giant phase. The most massive ones are missing completely, having already become very faint white dwarfs, neutron stars or black holes.)

The clear line of stars coming up from bottom right towards the left and then twisting off to the right can now be matched very accurately with theory. According to the age of the cluster, the line will lie in a different place. The 'knee' in the line of stars moves towards the bottom right of the diagram as the cluster ages. Its position in this cluster gives an age of 16 thousand million years, plus or minus 2 thousand million. We thus seem to be very close to our goal of 5 to 10% accuracy. However, the astrophysical parameters and the theoretical models could have systematic errors. A more realistic estimate of the extreme possible range of the age would be from 12 to 20 million years. Thus while the observations of cluster colour-magnitude diagrams can now be done accurately enough to tie down the range to this limit, further work is needed to get down to the desired accuracy, free from the possibility of systematic error.

Further improvements in the theory are needed and are possible. Further observational work is also needed not only on the colour-magnitude diagrams, but also in determining the astrophysical parameters better and making new tests of the predictions of the theoretical models. From where we stand now, it does seem that the goal of an accurate reliable age for the Universe is attainable if these investigations are pursued.

Alan Penny
Royal Greenwich Observatory (now at RAL)
Bob Dickens
Rutherford Appleton Laboratory

Giotto space probe launched

The European Space Agency (ESA) interplanetary space probe Giotto was successfully launched by an Ariane I launcher from Kourou in French Guiana on 2 July 1985. After three revolutions in its transfer orbit, the ESA Operations Control Centre in Darmstadt, West Germany, injected it into an Earth escape trajectory. It now continues on its way to encounter Halley's Comet on 13 March 1986, after a voyage of 700 million kilometres. It will pass through the comet's tail to within 500 km of the nucleus.

The comet's appearance will give us the first opportunity for close observation of a large comet from space and so extend our knowledge of the formation of the Solar System.

The USSR, Japan and the USA are also sending missions to intercept Comet Halley in March 1986. Two USSR Vega spacecraft will 'flyby' the comet at about 10,000 km; the Japanese Planet A mission will flyby at about 200,000 km; and the US International Cometary Explorer has been redirected towards the comet. The Americans will also be able to observe it from telescopes on board the space shuttle (the Astro payload) to be flown during March 1986. All the missions are party to the Pathfinder joint navigational effort which will make accurate targeting of all the spacecraft possible. For example, the Vega craft will encounter Halley's Comet a few days before Giotto and act as 'pathfinder' for it by establishing the position of the comet's nucleus with some accuracy.

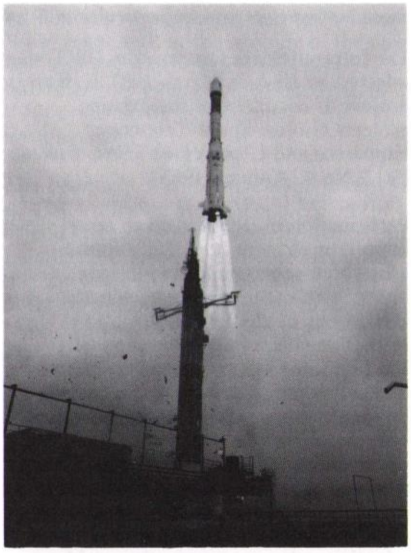
The Giotto spacecraft, built by the British Aerospace Dynamics Group, carries ten experiments including a camera for colour images of the coma and nucleus, three spectrometers for measuring the composition of the gas and dust in the cometary atmosphere and various plasma experiments for studies of the interaction between the solar wind and the comet. British research groups have been involved in two of the experiments on board Giotto, both funded by SERC research grants. The Dust Impact Detection System (DIDSY), which was built by Kent University (Principal Investigator — Professor J A McDonnell) will measure the mass of all cometary dust particles impacting on the Giotto dust bumper shield during its encounter with Halley. DIDSY comprises a suite of five independent subsystems, each one measuring the mass of impacting grains over a different but generally overlapping mass range. Detection techniques include impact plasma sensing, piezo-electric acoustic wave-measurement and thin film capacitor penetration.

Scientists at the Mullard Space Science Laboratory (MSSL) of University College London are leading an international team in providing an experiment on Giotto called the Johnstone Plasma Analyser (Principal Investigator — Dr A D Johnstone, MSSL). The experiment will investigate the formation of the plasma tail of the comet by measuring the energy and mass distributions of positively charged ions near the comet. There are three components to the analyser: the Fast Ion Sensor provided by MSSL, the Implanted Ion Sensor provided by the Max Planck Institute, Lindau, West Germany and the Data Processing Unit provided by the Instituto di Fisica dello Spazio Interplanetario, Frascati, Italy. Ground support equipment has been provided by the Kiruna Geophysical Institute (Sweden) and real-time analysis hardware and calibration facilities by the US Southwest Research Institute, with Rutherford Appleton Laboratory providing both high voltage supplies and computer peripheral equipment. Los Alamos National Laboratory has also provided computer peripheral equipment.

The Fast Ion Sensor, in which British interest mainly lies, will measure the three-dimensional distribution of ions in the energy range 10 eV to 20 keV with 4-second time resolution. It is designed to observe the solar wind ions as they interact with the ions from the comet and magnetic field structure. The instrument will be operated before arriving at the comet where it should be the first to detect its presence directly. It will monitor the conditions in interplanetary space, search for ions of interstellar origin and, emphasising the global nature of the investigations, carry out cross-calculation checks with similar instruments on the Japanese and Russian spacecraft and observe the undisturbed solar wind while those spacecraft pass through the comet.

As well as using Giotto for monitoring Comet Halley, UK scientists have access to a number of ground-based observational facilities provided or supported by SERC that are suitable for observing the comet on its journey towards and away from the inner Solar System. These facilities are the Anglo-Australian Telescope and the UK Schmidt Telescope, both at the Siding Spring Observatory, New South Wales, Australia; the Infrared Telescope (UKIRT) on Hawaii; and the Roque de Los Muchachos Observatory on La Palma, in the Canary Islands.

Groups from the British Antarctic Survey, the Royal Greenwich Observatory, the Royal Observatory, Edinburgh (ROE), and the Rutherford Appleton Laboratory will also be involved in observational work and related data analysis. Besides the professional observers, members of the British Astronomical Association amateur network will be feeding in information from their own observations to the International Halley Watch. This is an international network of over 900 professional astronomers from 50 countries and several thousand amateur observers, centred in the Jet Propulsion Laboratory in California. It will coordinate and standardise all ground-based observations and archive all Halley data (space-flight and ground-based) for present and future generations of scientists.



Giotto takes off aboard the Ariane-1 launcher on 2 July 1985.

SERC, the British Association Young Scientists and *the New Scientist* magazine ran an essay competition on Comet Halley for young people. The first prize, a five day trip to Kourou to witness the launch of the Giotto spacecraft, paid for by ESA, was won by Stuart Combes, aged 17, of Stanstead in Essex. Ten runners-up in the competition won a choice of scientific visits — to the British Association meeting at Glasgow in August, the Gala Tribute to Halley at Wembley Conference Centre in October, the Spaceworks Exhibition at the National Maritime Museum at Greenwich in November or day trips to SERC's Royal Observatories.

Halley's Comet has already been observed by UK scientists in its approach. In December 1984, astronomers from ROE and Kent and Leicester Universities, using UKIRT in Hawaii, made the first ever infrared detection of Halley's Comet as it approached the inner Solar System. Later, other ROE scientists obtained new photographs of the Comet using the UK Schmidt Telescope in Australia.

ESA selects the Space Observatory payload

In June, the Science Programme Committee of the European Space Agency (ESA) selected scientific teams to develop four focal plane instruments for the Infrared Space Observatory, due for launch in 1992. UK scientists will take an active part in the development of three of these instruments and in particular will have prime responsibility for the development of the long wavelength spectrometer.

The Infrared Space Observatory (ISO) was selected by ESA in March 1983 as its next project to complement the existing projects Giotto, Space Telescope, Hipparcos and Ulysses (see *SERC Bulletin* Vol 2 No 9, Autumn 1983).

Participation in ISO is seen to be an important element in SERC's future astronomy programme. Pioneering observations at infrared wavelengths carried out by the joint UK/USA/ Netherlands Infrared Astronomical Satellite (IRAS) have already led to a new understanding of the Universe, including topics as diverse as the origin of planetary systems, the formation of stars, and origin and evolution of galaxies. The ISO mission will capitalise on these early discoveries, enabling detailed studies to be carried out on sources identified by IRAS. UK scientists, who are among the world leaders in this field, will play a leading role in the mission, and will have exceptional capabilities for exploiting the results using complementary observations with the UK's ground-based telescopes.

The scientific payload for ISO will include an infrared camera, two spectrographs and a long-wavelength photometer. These instruments will be used to study a wide range of astrophysical objects such as planets, asteroids and comets, dense molecular clouds and protostars, the interstellar medium, galaxies and quasars, galactic structure and protogalaxies. The development of the focal plane instruments is to be carried out by four international consortia of scientists from the UK, France, West Germany, the Netherlands, Denmark, Italy, Spain and the USA. Some countries will participate in more than one instrument. The instruments are:

- a long wavelength spectrometer (LWS) consisting of a reflection diffraction grating used in two orders with an array of discrete detectors to provide a spectral resolving power of about 200 over the wavelength range from 45 to 180 μm. Two Fabry-Perot interferometers will be mounted in a wheel and either of them can be rotated into the beam to increase the resolving power to about 10^4. The Principal Investigator for the LWS is Dr P Clegg (Queen Mary College, London). Co-investigators include Dr P A R Ade (Queen Mary College), Drs I Furniss, W M Glencross, W A Towlson and M J Barlow (University College London) and Dr R J Emery (Rutherford Appleton Laboratory) together with scientists from France, Italy and the USA.

- a camera (ISOCAM) consisting of two 32 × 32 element arrays operating in the wavelength ranges of 3 to 5 μm and 6 to 17 μm. For extended sources, ISOCAM will provide superior results throughout the wavelength range as compared to similar instruments operating on large ground-based telescopes even at high spectral resolution; the same is true for point sources at lower resolutions. The Principal Investigator for ISOCAM is Dr C Cesarsky (CEA-Saclay, France). Professor M S Longair, Dr T Hawarden and Dr R Wade (Royal Observatory, Edinburgh and Edinburgh University) are co-investigators, together with scientists from France, Italy and Sweden.

- a photometer (ISOPHOT) with photometric, polarimetric and imaging capabilities from 3 to 200 μm and low resolution spectrometer ability from 3 to 16 μm. Each of the ISOPHOT subsystems has an excellent scientific justification; in particular the extension of photometric coverage and imaging to 200 μm, an area not covered by IRAS. The Principal Investigator for ISOPHOT is Dr D Lemke (MPI fuer Astronomie, Heidelberg, Germany). Dr R Joseph and Dr M. Selby (Imperial College of Science and Technology) and Dr J Abolins (Rutherford Appleton Laboratory), are co-investigators, together with scientists from Germany, Denmark and Spain.

- a short wavelength spectrometer (SWS), designed to operate in the wavelength range from 4 to 50 μm with a resolving power of 1000 to 6000 across the entire wavelength region, in normal mode. Higher resolving powers (up to 5×10^4) are possible over part of the wavelength range by use of Fabry-Perots; the instrument can therefore be used for both exploratory studies and detailed studies of known objects. The Principal Investigator for the SWS is Dr T de Graauw of the University of Groningen, Netherlands with co-investigators from Germany.

The Rutherford Appleton Laboratory will provide experienced space management and co-ordination for the UK involvement in the three instruments, together with appropriate software, engineering, scientific and product assurance support.

Spacelab 2: late but successful

Spacelab 2, with the two UK-prepared experiments that formed part of its payload, had a "superbly successful mission" on board NASA's space shuttle Challenger despite having its original launch aborted three seconds before lift-off on 12 July and its eventual launch two weeks later marred by one engine's shut-down during take-off. It finally brought back enough data to keep scientists busy for several years.

The eight-day mission, developed by the European Space Agency, carried a payload of 13 scientific experiments covering a wide range of disciplines from biology to astronomy. They were all designed to be exposed to space in the shuttle's cargo bay while the payload crew supervised their operation from within the cabin.

One of the UK experiments, CHASE (Coronal Helium Abundance Spacelab Experiment) was prepared by the Mullard Space Science Laboratory (University College London) and the Rutherford Appleton Laboratory. It was designed to carry out unique measurements of the outer atmosphere of the Sun. Known as the corona, this tenuous region is subject to violent magnetic storms and has a temperature in excess of 1 million degrees. At such temperatures, most of the coronal radiation occurs at Xray and far ultraviolet wavelengths to which the Earth's atmosphere is opaque. As a result, investigations of this highly interesting phenomenon are largely restricted to observations carried out from above the atmosphere.

The second experiment, an Xray telescope, was constructed by Birmingham University to look into the Universe at clusters of distant galaxies. Unlike Earth-bound observations, it was able to measure directly the distribution of the extremely hot gases known to be contained within such clusters. The results will be crucial to our understanding of how galaxies were formed in the early history of the Universe.

Royal occasion on Canary Islands

The ceremonies marking the opening of the new observatories on the islands of Tenerife and La Palma came to a climax on 29 June with the inauguration of the Roque de los Muchachos Observatory by King Juan Carlos of Spain assisted by Queen Margrethe of Denmark, King Gustaf of Sweden, Queen Beatrix of the Netherlands, President Weizsacker of West Germany, President Hillery of Eire, our own Duke of Gloucester and their families.

The formal ceremony followed dedications in each of the telescope buildings: the Carlsberg Automatic Meridian Circle was inaugurated by Queen Margrethe; at the William Herschel dome Sir John Kingman gave a short description of the telescope that will be the largest at the observatory; the Swedish telescopes were inaugurated by King Gustaf; and the Jacobus Kapteyn telescope by Queen Beatrix and President Hillery. These two Heads of state unveiled a plaque and, with a computer command, pointed the telescope to a star. There followed an unscheduled scramble up to the site of the Polaris Trail telescope led by King Juan Carlos.

The highlight for many SERC staff was the ceremony in the Isaac Newton telescope dome, when the Duke of Gloucester, in the presence of the whole royal party, unveiled the inaugural plaque and opened the telescope dome and mirror. The telescope executed a sedate bow to the royal party and the main mirror petals opened revealing the main telescope mirror. Queen Beatrix then set in motion a simulated night-time observing sequence by entering the simple command 'I BEGIN' on a computer console. To the royal party and all those unfamiliar with the experience, the result was startling: the telescope slewed round and the dome rotated to allow it to point to the sky. This dramatic effect, of such large structures moving in opposite directions, disoriented the visitors until they sorted out what was moving and what was not; then, their beaming smiles were rewards for those who had planned exactly this reaction.

The national anthems of all seven participating countries followed speeches on the political and scientific organisation of the new observatory, and the flags of the seven and the specially designed 'cosmic flags' were flown above the purpose-built stage and amphitheatre.

On the previous day, the West German solar telescopes at the Teide Observatory on Tenerife were inaugurated by President Weizsacker and, at the opening of the new Instituto del Astrofisica del Canarias buildings, the young heir to the Spanish throne was made an 'honorary atrophysicist'.

The banquets, lectures (including a superb talk by Professor Steve Weinberg on the origins of the Universe at the University of Laguna), ceremonies and speeches made this the most glittering send-off any observatory could have had in modern times. This reflects that these two observatories are, in their two fields of solar and nocturnal astronomical research, leading the world and that here some of the best astronomy in the world will be carried out for years to come.

Dr Peter Andrews
Royal Greenwich Observatory

Telescope structures on the move

The fabrication and assembly of the UK/Netherlands Millimetre-wave Telescope structures, destined for the Mauna Kea observatory on Hawaii, were completed at the factory of Genius Fabricage BV, Ijmuiden in the Netherlands, by March this year. There then followed dynamic tests of both the elevation and azimuthal drive systems, carried out by staff from the Rutherford Appleton Laboratory (RAL) and the Mullard Radio Astronomy Observatory, Cambridge. Although the telescope was incomplete, the results of the tests indicate that the operational specifications for the drive systems will be met comfortably.

To celebrate its fortieth anniversary, Genius held two open days in April with the telescope structures as the central display. On the first of these days, Prince Claus of the Netherlands formally presented the structures to the Director of RAL, Dr Geoff Manning. The ceremony was attended by more than a thousand invited guests, many of whom were customers of the company.
The structures were then dismantled and shipped to Hawaii where they arrived in July. Staff from RAL and the Netherlands are now taking up residence in Hilo to supervise the construction of the telescope and its supporting systems. It is expected that the installation will be ready for tests to begin early in 1986 and for commissioning to be complete by early 1987; it will then be handed over to the Royal Observatory, Edinburgh, ready to begin operating in April 1987.

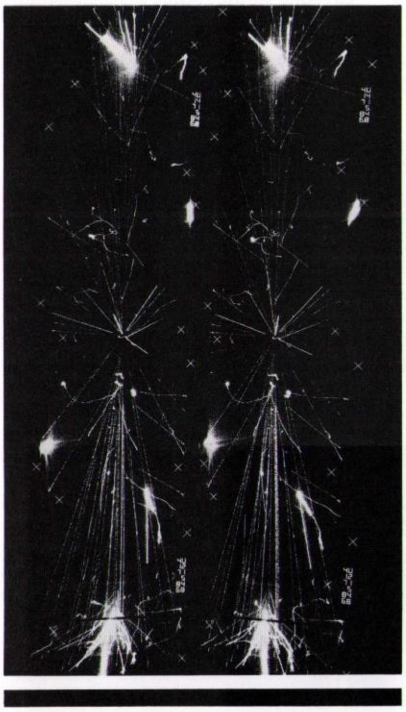
HRH Prince Claus of the Netherlands operating the UK-NL Millimetre-wave Telescope at its presentation to Dr G Manning, Director of the Rutherford Appleton Laboratory (right). On the left are Professor H van der Laan of Leiden University and H Bruggink, Director of Genius Fabricage BV.

The Pulsed Collider at CERN

The first results from the world's highest energy collisions

The Super Proton Synchrotron (SPS) accelerator at CERN has enjoyed considerable fame over the past few years as the instrument which made possible the discovery of the W and Z bosons, the quanta of the 'electroweak' force. The collision energy of 540 GeV necessary for these discoveries in 1982-3 was achieved by accelerating counter-rotating bunches of protons and antiprotons from 26 GeV (the energy at which they are received from the proton synchrotron) up to 270 GeV in the SPS, and leaving them to coast for many hours while head-on collisions could be observed in detectors placed at two points around the SPS ring. The emphasis with this 'normal' collider operation was to maximise collision rates to increase the chance of detecting rare collisions. There is a maximum energy of particles that can be stored in the SPS, because of the power dissipation that can be allowed in the main magnet coils; initially 270 GeV, by 1984 this had been raised to 315 GeV.

However, Easter 1985 saw the successful completion of the first run of the 'Pulsed' Collider at CERN, in achieving a world record collision energy of 900 GeV for particle physics experiments. This employed a new technique, suggested by the UA5 Collaboration involving Cambridge University, to sidestep this power limitation by pulsing the stored particles, that is accelerating them briefly to 450 GeV and then decelerating them back down to 100 GeV, the cycle being repeated every 22 seconds. With a 4 second 'flat top' at 450 GeV, the power consumed averaged less than in 'normal' DC operation, and the thermal 'shock' to the magnets remained within acceptable limits. To achieve this 50% leap in collision energy required an extraordinary feat of accelerator engineering, with the 'tune' of the machine, that is the complicated pattern of focusing, defocusing and bending fields that guide the particles, having to be maintained to better than 1 part in 10^4 at every moment of the acceleration-deceleration cycle.



Example of a 900 GeV collision of proton and antiproton at the new SPS 'Pulsed' Collider at CERN. It is a stereo image pair of one of 115,000 events taken by the UA5 streamer chamber detector in March 1985, involving Cambridge University.

A main physics aim of the UA5 experiment is to approach the energy of those cosmic ray experiments carried out at Mount Fuji in Japan, Mount Chacaltaya in Bolivia, and in the Pamirs in the Soviet Union, at which a variety of exotic events starts to appear which have no ready explanation in terms of current ideas in particle physics. These events go by various names, such as Chirons, Geminions and Centauros, and are produced when cosmic ray particles with energies in excess of a few hundred TeV (1 TeV = 1000 GeV) interact with the Earth's atmosphere. The 900 GeV centre-of-mass energy of the Pulsed Collider is equivalent to the energy released by 430 TeV protons striking a stationary proton target, and so should be enough to produce these events artificially for the first time.

The most famous of these, the Centauro events (of which six examples have been seen in cosmic rays), are characterised by having *inter alia* a very high multiplicity (about 100) of produced particles and, instead of the large number of secondary photons that usually appear (from decaying π^0-mesons), a virtual absence of such photons. The UA5 streamer chamber detector is ideally suited to unravelling very complicated events: it has a large sensitive volume ($6 \times 1.25 \times 1m^3$), and is viewed with high optical resolution via image intensifiers by six stereo views, of which one pair is shown in the accompanying figure. Events of relatively high multiplicity are not uncommon at Collider energies — in fact a significant discovery by UA5 at 540 GeV was of a strong increase in the proportion of high multiplicity events (having say three times the mean multiplicity), when compared with events found at the Intersecting Storage Rings (ISR) of 20-60 GeV energy. (An explanation of this phenomenon is still awaited from the candidate theory of the strong interaction, quantum chromodynamics — QCD; possibly it is due to an enhanced probability for interactions among the 'gluons' radiated by the colliding proton and antiproton). This trend has now been seen to continue to 900 GeV — it was among the first results from the Pulsed Collider to be presented by UA5 at the Multiparticle Dynamics Conference held at Tel Aviv in June.

The average event at 900 GeV has been found to possess about 35 charged particles, so events with 100 charged particles are not uncommon, occurring about 0·4% of the time. However, to prove that among these events there are hiding the mysterious Centauros is not so simple — the photon component has to be checked, for example. UA5 does this by observing conversions into electron-positron pairs of individual photons in converting material just before they enter the streamer chamber, but this requires careful measurement and analysis which is still in progress. First indications are, however, that any Centauro component could be present only at the 0·5% level or less. More concrete results will emerge in the coming months.

Should these exotic cosmic ray events not be made at accelerators they will require some other, presumably astro-physical, explanation. Theorists some time ago suggested that Centauros perhaps result from a metastable, colourless (in the sense of QCD) cluster of quarks, a 'glob', which could have penetrated the atmosphere down to mountain level and decayed, perhaps into baryons-antibaryons only (which would explain the absence of π^0s) above the cosmic ray detectors. Such ideas have achieved renewed topicality with the recent observation of anomalous radiation from the binary system Cygnus X−3: the fluxes of muons and of high energy photons pointing across our galaxy to an origin in this source probably cannot be reconciled with our current understanding of particle physics. Some theorists have suggested a new type of 'quark star' as responsible for these and other cosmic ray phenomena, such as Centauros. As with the 'big bang' theory of cosmogenesis, another important link of particle physics with cosmology or astrophysics is emerging.

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The first direct observation of beauty particles

A team of European and Japanese physicists at CERN has recently obtained a photographic record of the associated production of a pair of so-called 'beauty particles'. Their production, decays and the subsequent decays of their daughter 'charmed particles' were all observed within a single sheet of nuclear photographic emulsion, the whole sequence of these events taking place in about one millionth of a millionth of a second.

The existence of beauty particles has already been established by experiments performed at the electron-positron collider machines in Germany and the USA. However, in these experiments the presence of beauty particles was deduced indirectly from the configurations of their decay particles, not from the direct observation of their own tracks.

Beauty particles are known to be heavy and contain b quarks, the fifth in order of ascending mass of the predicted six 'flavours' of quark in the current theory. Since flavours are known to be conserved in strong interactions the production of a beauty particle requires the simultaneous production of an anti-beauty particle, ie one containing a $\bar{b}$ quark. Moreover, a measure of the energy required to produce beauty particles is their heaviness — and they are therefore both difficult to produce and quick to decay.

The CERN experiment (WA75) was designed specifically to observe beauty particles with these expectations in mind. To achieve this goal, the hybrid apparatus containing both nuclear emulsion and electronic particle detectors was exposed to the high energy (350 GeV) beam of π^- mesons at the CERN Super Proton Synchrotron. The nuclear emulsion allows direct observation of the production and subsequent decay of particles with lifetimes as small as 10^{-14}sec whereas the known predominant decay of beauty particles to charmed particles means that their associated production would be characterised by the observation of a pair of sequential decay processes, a topology almost impossible to reproduce by any known background phenomena.

Eighty litres of Fuji and Ilford emulsions were exposed to some 4×10^9 pions and about 300 million of these interacted. Only an extremely small fraction of these interactions would be expected to produce beauty particles. Clearly the microscopic analysis of such a vast number of interactions would not be feasible. Instead the ability of beauty mesons to decay into energetic muons was used to select likely events for extensive scrutiny. This requirement reduced the number of interactions to be further studied to about one million. Having measured the momentum and direction of the muon in a conventional magnetic spectrometer, a more stringent off-line requirement — that its momentum transverse to the beam direction should exceed 1 GeV/c — reduced the number of events to be studied still further, to a much more manageable ten thousand or so.

Then the convergence of particle tracks observed in planes of silicon microstrip detectors upstream and a vertex detector downstream was used to define the search volume in the emulsion to less than one cubic millimetre. Since there are very few interactions in such a small volume, the matching of directions of tracks seen in emulsion with those observed in the vertex detector enabled the correct interaction to be identified and any decays of neutral particles to be time-correlated with the primary interaction.

Although the analysis of the data collected in two runs in Autumn 1984 and Spring 1985 is only in its early stages, an event exhibiting all the features expected of the production and subsequent decays of a beauty-antibeauty particle pair has been observed. One track from the primary interaction was observed to undergo a sharp change in direction at (1) (see figure), its resultant direction matching well with that of a high energy, high transverse momentum, negative muon seen in the magnetic spectrometer. Subsequent searches revealed the decays of two neutral particles, one at (2) into four charged particles, the other at (3) into two, one of which was observed to change direction at (4) and then match that of yet another negative muon recorded in the magnetic spectrometer. The excellent matching of the tracks in this sequence with those in the vertex detector established beyond doubt the overall correlation of the various features of the event.

The most obvious interpretation of the event is as the production of a $B^- \bar{B}^o$ beauty pair and their subsequent decays to charmed particles via the reactions

$B^- \rightarrow \mu^- + D^o$ + neutrals
  └→ four charged particles
$\bar{B}^o \rightarrow D^-$ + one positively charged particle + neutrals
  └→ μ^- + neutrals.

The energies of the beauty particles were estimated knowing the angular distributions of the decay products and the muon energies. The resulting flight times were 0.8×10^{-13}sec for the B^- and 5×10^{-13}sec for the $\bar{B}^o$. These are to be compared with beauty particle lifetimes a little in excess of 10^{-12}sec obtained from other experiments.

Finally, when allowance has been made for the overall efficiency of detecting beauty particles by this means, the finding of one event corresponds to a beauty particle production cross section of about 10 nanobarns (10^{-36} m^2). This is to be compared to typical hadron cross-sections of tens of millibarns. This means that less than one high energy pion interaction in a million produces beauty particles, thereby underlining the need for rigorous selectivity and a high discrimination of detection in this kind of experiment.

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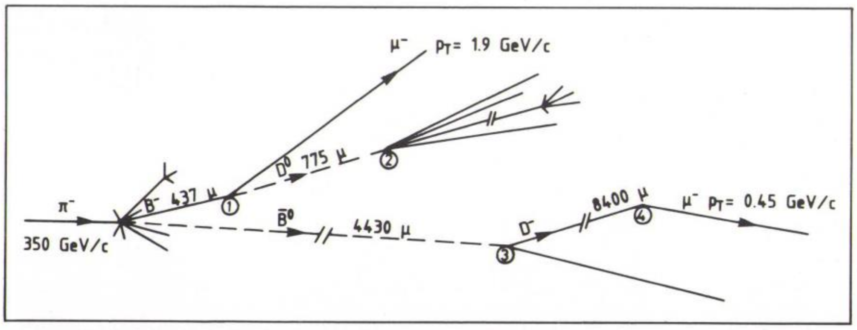

The creation of Beauty. A pion, entering from the left, interacts to produce the short-lived Beauty-carrying particles B^- and $\bar{B}^o$.

Recoil separator on the NSF

An experimental programme to study nuclei far from stability under extreme conditions is underway at the Nuclear Structure Facility (NSF) at Daresbury Laboratory. A variety of experiments probing nuclear matter are taking place and are providing stringent tests of our theoretical understanding of the nucleus as well as uncovering fascinating new puzzles.

Using the exotic heavy-ion beams from the NSF, unstable, highly proton-rich nuclei can be populated using fusion reactions. However, the nuclei are produced as recoils moving at near-zero degrees, and some method is needed to resolve them from the intense flux of beam projectiles and other reaction products.

The recoil separator uses a technique of selecting particles according to their velocity and thereby separating the recoiling nuclei of interest from the higher velocity beam particles. It is also designed to identify the mass and atomic number of the detected nucleus. Nuclei far from stability are not only uniquely identified but their excited states can be studied using the techniques of gamma-ray spectroscopy.

The separator consists of a series of magnetic and electric fields which are used to select a particular recoiling nucleus from all other forward-going charged fragments. This selection takes place in two velocity filters, each of which consists of mutually perpendicular magnetic and electric fields which are also perpendicular to the beam direction. The recoiling nuclei of interest are selected by their velocity using these filters and the intense unscattered beam, which has a higher velocity, is rejected. Careful design of the velocity filters and other beam transport elements was necessary in order to achieve a rejection factor for beam particles of 10^9 or better. The first magnetic quadrupole triplet is used to produce roughly parallel trajectories through the velocity filters and the second produces a velocity-dispersed image at the velocity slits. Typically, a range of velocities of $\pm$ 2% is accepted by these slits.
The particles accepted are bent by a 50° dipole magnet and, after being focused by a third magnetic quadrupole triplet, are dispersed in mass A (actually dispersed in A/q, where q is the charge state of the ion). The mass is determined by a position-sensitive detector placed in front of a split-anode ion chamber which determines the atomic number. In total the recoil separator has 14 magnets and four electrostatic deflectors (up to 300 kV each) which are precisely set and monitored under computer control.

In the first commissioning experiments, proton-rich nuclei in the mass 130 region were investigated. These nuclei were populated by bombarding a ^{54}Cr target with a 275 MeV ^{80}Se beam. The spectrum obtained in the position-sensitive detector is shown in the figure, and four distinct nuclear masses are clearly resolved (masses 129, 130, 131, 132). Gamma-rays associated with these masses were recorded in a germanium detector close to the target and identify the recoils as cerium nuclei (Z = 58). These experiments have demonstrated not only the recoil separators's capability of measuring both the atomic mass and number directly in coincidence with the gamma-decay of the separated nucleus, but also its ability to do this for a single nucleus in the presence of billions of beam particles.

The recoil separator will often be used in conjunction with other major pieces of detection equipment. An example is a large, multi-detector array currently being developed for gamma-ray spectroscopy. This will be positioned close to the target position, to provide very high detection efficiency in order to measure the gamma-decays which occur within 10^{-10} seconds of the formation of the recoil. The physics interest in using combinations of equipment of this type with the recoil separator is considerable, and many groups are planning research programmes aimed at exploiting this latest addition to the NSF. With its unique ability to identify a particular nuclear product directly in coincidence with the decay radiation, the recoil separator system is a powerful tool which will enable UK scientists to continue to explore new and hitherto inaccessible areas of exotic nuclear spectroscopy.

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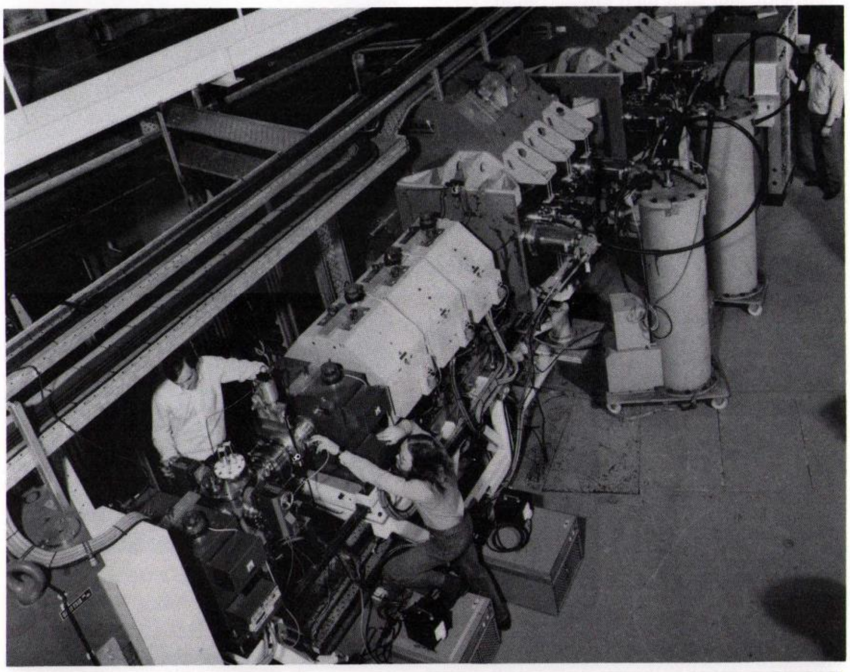
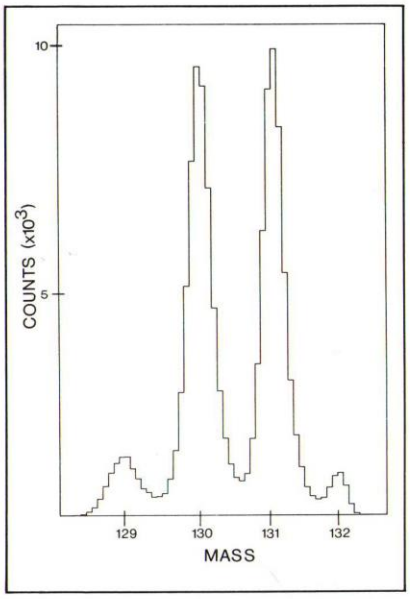
Daresbury Laboratory



General view of the recoil separator looking upstream.



Mass spectrum recorded at the focal plane of the recoil separator of fusion products resulting from the bombardment of ^{54}Cr nuclei with 275 MeV ^{80}Se ions.

Biology and chemistry at the CLF

Large lasers such as the Nd-glass laser VULCAN and the KrF gas laser SPRITE are remarkable energy concentrators capable of raising material placed at a focus to temperatures greater than 10^7 degrees Kelvin at pressures of over 10^8 atmospheres. Much of the research programme at the Central Laser Facility (CLF) at the Rutherford Appleton Laboratory is concerned with the properties of matter in such extreme conditions but an increasing fraction of the effort is now being devoted to exploiting the intense Xray emission which results. Recent Xray microscopy experiments at the CLF have already shown features not seen before in biological specimens.

The specimens to be Xrayed, which may be wet and up to 10 microns thick, are placed in contact with an Xray sensitive resist behind a thin silicon nitride window in a vacuum-tight holder. The assembly is mounted in the evacuated target chamber a few centimetres from the target on which the laser will be focused. For biological work a plastic target is used since it gives a spectrum concentrated in the window between the K absorption edges of carbon and oxygen. This provides a natural contrast requiring no staining to reveal the distribution of organic material in the presence of water.

A single laser shot giving a burst of Xrays lasting less than 100 nsec is sufficient for the exposure. The appearance of the living specimen can be recorded despite the lethal radiation dose needed for high resolution because there is no time for any change in morphology to take place.

After the shot, the resist is developed to provide a relief image with a resolution better than 100 nm. It may then be examined at high magnification with a microscope. Scientists from ten laboratories in the UK and three in the USA exposed more than 300 specimens in a one-month experiment this spring using both VULCAN and SPRITE to provide flash Xray sources. Two views of a resist exposed during this run are illustrated. The sample was fresh, untreated epidermal hair from a foxglove and the images show internal structure not seen before. Sub-micron structure is clearly visible. The threadlike features are provisionally identified as transcellular strands of cytoplasm which may indicate continuity from cell to cell. The possible existence of such structures in plant tissue has been conjectured before but direct evidence has been lacking till now.

Multidisciplinary research

The smaller lasers at the CLF provide tunable coherent radiation for multi-disciplinary research.

The availability of high power line-narrowed ultraviolet radiation has been of particular importance. It has enabled users from the chemistry community to break new ground in the application of powerful resonance Raman spectroscopic techniques using the electronic resonances which occur in the ultraviolet to couple to specific parts of molecules.

An example from biochemistry is shown in the diagram which contains a Raman scattering peak due to a transient acyl enzyme intermediate in an enzyme catalytic reaction, the first time such an intermediate has been observed in natural conditions. Previous experiments using longer wavelength radiation to excite the scattering have had to use a chromophore which does not occur in the natural process. The study of such resonance Raman spectra will make it possible to monitor the behaviour of bonds undergoing catalytic transformation in the active centre of the enzyme and should ultimately contribute to finding new catalysts of industrial, biotechnological and medical importance.

To cater for the increased demand SPRITE has now joined VULCAN as a scheduled user facility and the smaller lasers have been regrouped and added to in a newly named Laser Support Facility (LSF). They will cover the spectrum from the vacuum ultraviolet to the near-infrared and will include a picosecond laser as well as the excimer and dye lasers presently in use. The LSF also includes a Laser Loan Pool set up with contributions from the subject committees of Science Board. Full details of lasers available for use at the CLF or on loan may be obtained from Dr M H Key, Head of Laser Division, RAL.

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Rutherford Appleton Laboratory

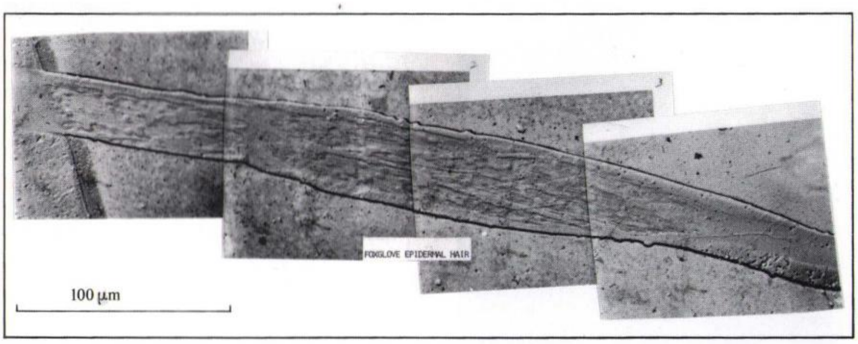

Figure 1: Xray image of fresh untreated foxglove epidermal hair recorded on resist and viewed with an optical microscope.

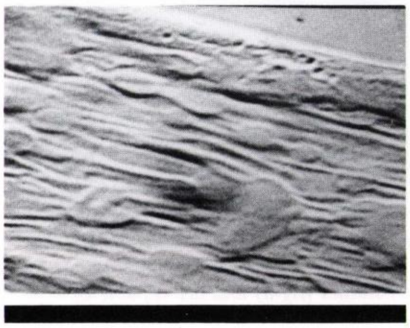

Figure 2: Electron microscope image of part of the resist shown in figure 1. (Unpublished data by courtesy of P C Cheng, R W Eason, R Feder, A G Michette, F O'Neil, R J Rosser, P T Rumsby and A D Stead)

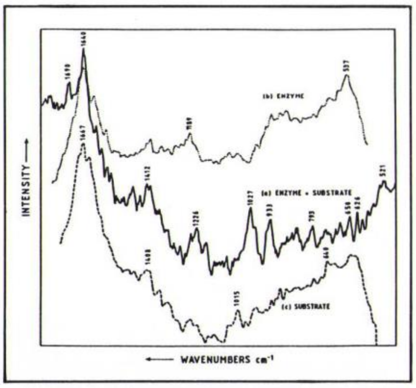

Figure 3: Ultraviolet resonance Raman spectrum of (a) N-Acetyl-L-Phe-Gly-papain; (b) papain and (c) substrate. (Data by courtesy of P J Tonge, C W Wharton, R J Salewski, P J Killough and R J Hester)

SERC support for high pressure research

The use of high pressure as a tool for the investigation of solid state phenomena has become increasingly important in recent years. Recent advances in technique, principally involving the diamond anvil cell, have revolutionised high pressure studies. A large number of experimenters are being attracted from a wide range of disciplines such as chemistry, physics, biology and material science to include high pressure techniques. SERC supports such studies via a number of channels including the High Pressure Facility provided at the Standard Telecommunication Laboratories (STL), Harlow; SERC's Daresbury and Rutherford Appleton Laboratories and direct grants to the scientific community. The purpose of this *SERC Bulletin* series is to outline the principal facilities available via the SERC. Volume 3 No 2 (June 1985) contained an article reviewing high pressure neutron facilities and here we review work involving the Synchrotron Radiation Source (SRS). Concluding articles will discuss the High Pressure Facility at STL and research in the higher education system.

High pressure research at the SRS

The unique properties of synchrotron radiation are ideally suited to high pressure studies. The radiation is a white continuum extending from Xrays, through ultraviolet and visible wavelengths to the far infrared region. Further, it is pulsed, plane-polarised and very intense, being extremely well collimated in the plane of the accelerator. High pressure facilities available to experimenters are being rapidly built up. Currently the high pressure equipment is based on two different designs of diamond-anvil cells for Xray measurements. These cells (figure 1) have been designed for single-crystal measurements up to 100 kbar (1 kbar = 0.1 GPa = 10^3 atm) and for energy-dispersive powder diffraction up to 500 kbar. Pressures are measured via the optical fluorescence shift of ruby held under pressure with the samples, surrounded by a pressure-transmitting fluid, thus ensuring hydrostaticity. Further developments include the use of Bridgeman anvil cells for both EXAFS and powder diffraction.

To date, three different experimental techniques have been employed at high pressures using the SRS.

EXAFS

Analysis of an Xray absorption spectrum can yield valuable local structural information (specific interatomic distances and coordination numbers) even in non-crystalline phases. It should be possible not only to investigate the effect of pressure on the interatomic distances of amorphous materials and liquids but also to obtain important information on new high-pressure structural phases including valence changes. Most high pressure EXAFS studies have employed Bridgeman anvil cells but for the highest pressures (above 100 kbar) the use of diamond anvil cells is preferable. One disadvantage is the presence of Bragg peaks from the diamond windows which overlay the EXAFS spectra. Dr D M Adams (Leicester University) and the author have succeeded in obtaining EXAFS spectra from a gasketted diamond anvil cell and have studied pressure-induced changes in metal carbonyls and the Jahn-Teller distorted ion $[CuCl_4]^{2-}$. Figure 2 is an example of an EXAFS spectrum obtained at the K-edge of copper in $[(C_2H_5)_3NH]_2CuCl_4$ using focused radiation at about 154 kbar. Removal of the Bragg peaks and Fourier transformation yielded accurate Cu-Cl distances.

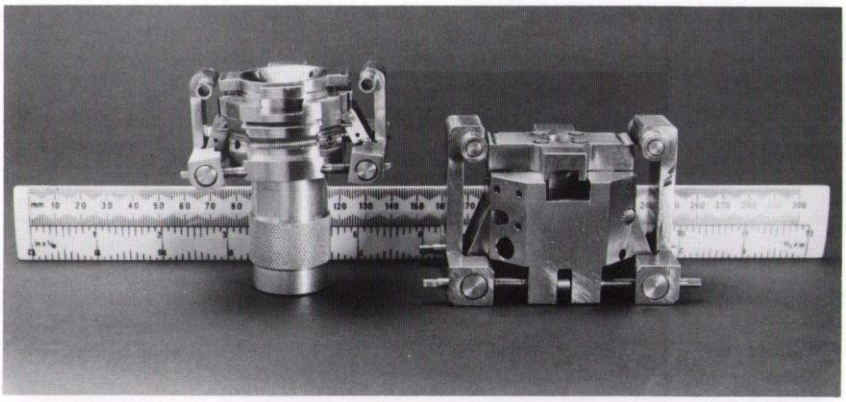

Figure 1: Two diamond anvil cells available for use with synchrotron radiation. These cells are for single crystal (left) and powder diffraction studies (right) and are capable of generating pressures to 100 and 500 kbar respectively.

Powder diffraction

The powder diffraction station at the SRS is situated on the wiggler beam line which provides hard Xrays to about 100 keV. This smooth continuum is exploited in energy-dispersive powder diffraction which has become the principal method of

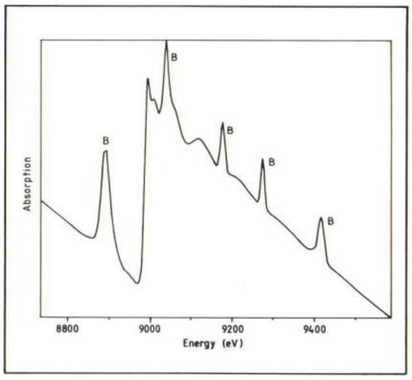

Figure 2: An EXAFS spectrum of $[C_2H_5)_3NH]_2CuCl_4$ phase II under high pressure. The spectrum is contaminated by the presence of Bragg peaks from the diamond windows (B).

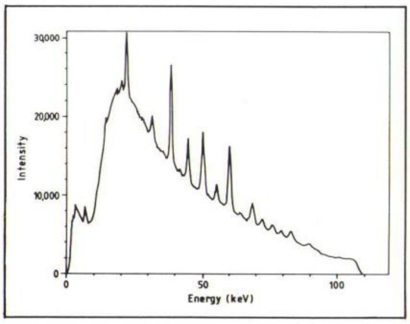

Figure 3: An energy-dispersive diffraction powder pattern of potassium chloride measured at 30 kbar. The structure has transformed from the rock salt structure (B1) to the caesium chloride structure (B2).

obtaining *quantitative* structural information at high pressures. In this technique both the sample and the detector are fixed and the pattern is observed as a function of energy (wavelength) by the energy-resolving detector. Because of the intensity and collimation of synchrotron radiation, extremely small samples can be studied and it is very fast. Useful diffraction patterns can be obtained in a few seconds and it is thus ideal for the study of kinetic phenomena. Figure 3 is a powder pattern of potassium chloride at about 30 kbar in a diamond anvil cell. At these pressures it has transformed to the caesium chloride structure, and analysis of the peak positions gives information concerning the compressibility of the material. The observation of the high-index reflections increases the accuracy of refinements and allows small deviations from high symmetry to be resolved.

Far infrared spectroscopy

Spectroscopy in the far infrared and submillimetre regions has always been severely hampered by the lack of bright and intense broad-band sources. It has been shown that improvements of between 6 and 25 are obtained by the use of synchrotron radiation compared to conventional mercury arc lamps. The difficulty in obtaining far infrared spectra at high pressures can thus be overcome by the use of synchrotron radiation. Figure 4 shows the spectral background (5-140 cm^{-1} region) obtained through a 0.6 mm hole — simulating the aperture available in a diamond anvil cell — observed by Dr J Yarwood (Durham University) and Dr T Shuttleworth (Birkbeck College).

Future prospects

Further experiments being planned include Laüe diffraction using single crystals, time-resolved fluorescence spectroscopy and high resolution powder diffraction. Improvements in facilities including cryostats, laser heating and position-sensitive detectors are planned, thus ensuring that the SRS has a very bright future for high pressure studies.

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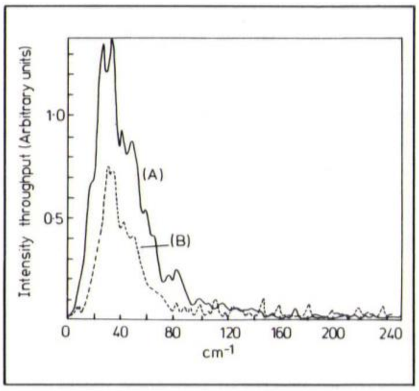


Figure 4: Spectral background obtained through a 0.6 mm hole: (A) using the Synchrotron Radiation Source at 180 mA; (B) with a mercury arc lamp (resolution is 4 cm^{-1}, data collection time is 70 minutes).

NATO science meeting at Edinburgh

At the invitation of the UK Government, represented by the Hon Peter Brooke, Minister for Science at the Department of Education and Science, the NATO Science Committee held its summer meeting this year in Edinburgh in May. The Committee's present Chairman is Professor Henry Durand of France, and its members are eminent scientists and engineers from the 16 member countries of the Organisation. The Committee's programmes aim to promote civil scientific exchanges of people and knowledge within the countries of the Alliance through fellowships, advanced study institutes and workshops, collaborative research grants and special programmes in selected scientific areas. It also provides financial and programme assistance designed to strengthen the scientific and technological infrastructures in the less favoured countries of NATO. Since its inception in 1958, the Committee has supported almost a quarter of a million scientists in pursuing these objectives.

The programme for the Edinburgh meeting extended over three days of business sessions, at one of which Sir Robin Nicholson gave a presentation on the support of science in the UK, and visits to scientific institutes. These included aspects of information technology at Edinburgh University, an overview of the Edinburgh Centre for Rural Economy; and the programmes of the Royal Observatory, Edinburgh. Mr Brooke, as well as hosting a reception at Edinburgh Castle, was able to join the Committee for part of one of its morning sessions and on two visits. The Committee was welcomed by the Lord Provost on behalf of the City of Edinburgh and a dinner was given in its honour by Edinburgh University.

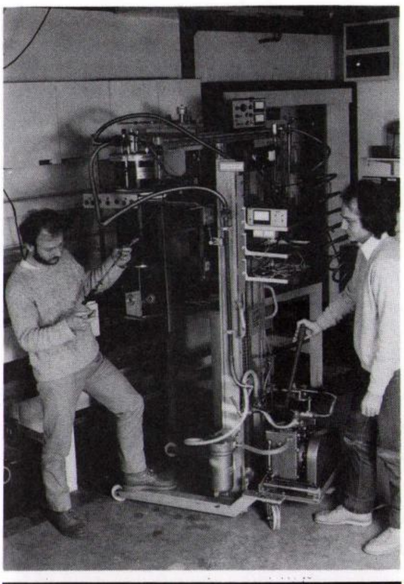
Sir John Kingman, the UK member on the Committee, describing some of the work of the UK Schmidt Telescope (UKST) to Professor A Muller of Luxembourg (left) and special guest Professor I I Rabi, who won the Nobel Prize for Physics in 1944 and was the United States member of the NATO Science Committee from 1958 to 1978. Dr E E David, President of Exxon Research & Engineering Company, the present United States member of the Committee, is on the right taking a close look at one of the spectacular objects recorded on a night sky photograph; standing next to him is Dr R D Wolstencroft of the Observatory staff.

Magnetic circular dichroism spectroscopy of metalloproteins

For the past ten years or so, a group at East Anglia University in Norwich has been applying magnetic circular dichroism (MCD) spectroscopy to probe the electronic and molecular structures of a range of metalloproteins especially those containing haem groups, copper ions and iron-sulphur clusters.

The basic principles of the technique were established through the 1960s by inorganic chemists interested in assigning the electronic spectra of transition-metal complexes. However, it was clear from the outset that application of the technique to the study of metal centres in metalloproteins would yield information about coordination geometry, and the electronic states. The full exploitation has had to await the development of new cryogenic techniques and methods of generating circularly polarised light over a wide wave length range. There are now three aspects of the technique of MCD spectroscopy which are currently being applied to the study of metalloproteins. The subject is in a state of rapid development and the UK is fortunate in having established a world lead, through the excellent support of the Biological Sciences and the Chemistry Committees of SERC and innovative developments in cryogenics by the Oxford Instrument Company.

Proteins which contain transition metal ions comprise a large class of biological materials involved in a wide range of enzymatic catalysis. For example, many of the processes of assimilation such as the biological fixation of atmospheric nitrogen involve chains of metal-centred catalysts, as do the energy-yielding respiratory processes of aerobic and anaerobic organisms such as the reduction of O_2 to water, CO_2 to CH_4, SO_4^{2-} to H_2S, or protons to H_2. Some of the catalysts are embedded in membranes and are involved in electron transport and in energy coupling and conserving processes using the proton. In order to understand how these important biological machines work at the molecular level it is necessary to have detailed structural information, especially about the metal centres. Questions such as the number and nature of the liganding groups which bind the metal centre are often difficult to answer. We also need to understand the oxidation and spin states of the metals. Control of these parameters can lead to subtle geometrical changes at the metal centre and hence to the coupling of electron transfer to conformational change. Spectroscopy provides dynamic probes which can inspect the structures of individual metal centres. A whole range of complementary spectroscopic techniques is required, namely electron paramagnetic resonance (EPR), electron nuclear double resonance (ENDOR), Mössbauer, resonance Raman and magnetic circular dichroism (MCD).



Dr J Peterson and Dr P M A Gadsby loading a protein sample into the superconducting magnet used for MCD and PROD spectroscopy at East Anglia University.

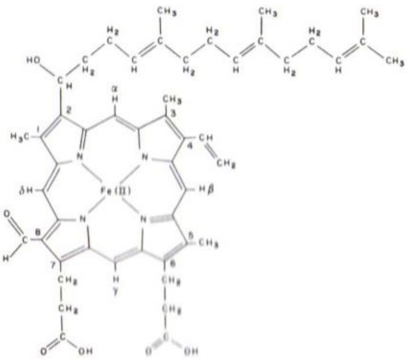
The first important step was the development of the application of **low-temperature MCD** spectroscopy to the study of frozen aqueous solutions of metalloproteins. The MCD spectrum of a paramagnetic centre is dependent on temperature and magnetic field. At low temperature (less than 4.2 K) the MCD spectrum is intense and dominates the contribution from the diamagnetic species present. This provides a method of detecting the optical spectrum of one chromophore in the presence of others. The intensity variation of the MCD as a function of temperature and field can be expressed in the form of a magnetisation curve. The shape of this curve is related to the ground state magnetic parameters such as spin, S, g-values and zero-field splittings.

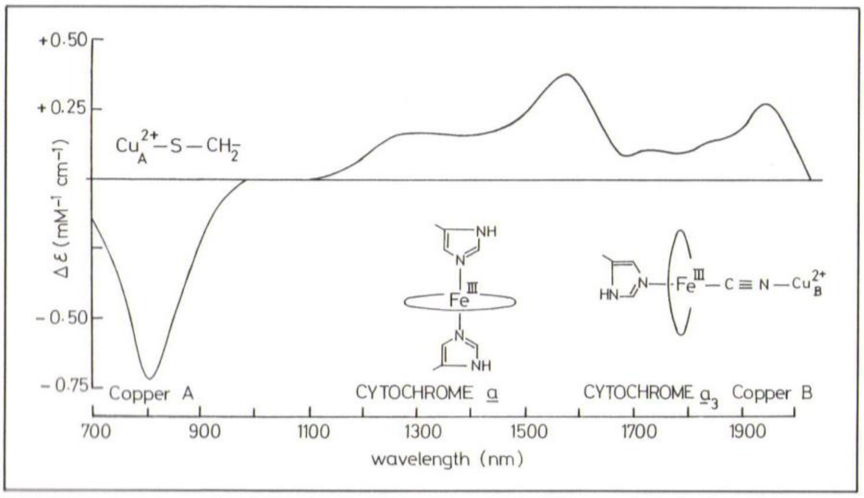
The second useful aspect of MCD spectroscopy is that it extended the accessible wavelength range of optical spectroscopy into the **near-infrared spectral region** currently to 3000 nm and possibly to 5000 nm. This wavelength region contains absorption bands involving the d-electrons of the metal directly. These transitions are often diagnostic of spin-state, the coordination geometry of the metal ion and the nature of the liganding groups. The MCD spectra detect such electronic transitions even in the presence of overlapping vibrational transitions. An instrument capable of measuring in this region is currently operating at Norwich.

The technique has been specially useful for probing the centres of a metalloprotein which contains more than one metal centre. Such an enzyme is cytochrome c oxidase, the terminal respiratory enzyme of all aerobically respiring organisms, which contains two haem groups and two copper ions (cytochromes a and a_3 and copper A and B). By examining the near infrared region MCD spectrum of this enzyme at low temperature and by a detailed study of the MCD magnetisation characteristics of each feature in the optical spectrum, we were able to assign each band to a distinct metal centre and hence to derive some structural information about each centre. The conclusions are summarized on figure 1. The particular form of the enzyme studied was the cyanide inhibited state. The magnetisation studies of the peak at 1950 nm showed that the species giving rise to this feature is a ferromagnetically coupled pair of metal ions. This situation is so far unique in proteins. The fact that the electron spin on the two metal ions is ferromagnetically coupled implies a linear cyanide bridge between the iron and copper ions. Since the cyanide ion is an inhibitor of the enzyme competitive with the substrate di-oxygen, it is clear that O_2 also can bind between the iron and copper sites in a linear bridge. The mechanism of reduction is yet unclear but presumably involves the donation of electrons from both ends of the bridge. We now have additional evidence that the act of transferring electrons from the two electron storage centres, the other haem and copper sites, causes the iron and copper ions binding O_2 to move apart and hence assists in the bond breaking to generate water.

A second example involves a protein extracted from the bacterium *Pseudomonas aeruginosa,* which catalyses the oxidation of cytochrome c by hydrogen peroxide. This protein, cytochrome c peroxidase, contains two haem groups

Figure 1: The MCD spectrum at 4.2 K and 5.1 Tesla of cyanide-inhibited cytochrome c oxidase. The spectral features arising from each of the four metal centres in the protein are indicated. The haem, which is represented by the symbol (Fe^{III}) has the structure:





covalently linked to a single polypeptide chain. One of the haem group acts as an electron storage centre. The other is unreactive towards the substrate, H_2O_2, until the first haem group is reduced, at which the protein undergoes a conformational change causing the second haem to lose one of its protein ligands and to bind H_2O_2.

This provides a simple example of the redox linked conformational change which may be taking place in cytochrome c oxidase.

The third and most recent application of MCD spectroscopy to the study of metalloproteins is to use it as a sensitive **optical detector of paramagnetic resonance**. The Norwich group have coined the whimsical acronym Paramagnetic Resonance by Optical Detection (PROD). The intensity of the MCD signal of a paramagnet at low temperature depends upon the differential population of the Zeeman split sub-levels of the ground state. If the thermal population is perturbed by the application of a monochromatic microwave field as in an electron paramagnetic resonance (EPR) experiment, the MCD intensity is partially quenched. The MCD signal intensity is a sensitive way of measuring spin temperature and of determining paramagnetic resonance. The advantages of such an experiment are several. First, each peak in an optical spectrum can be associated with an EPR signal or lack of one. Secondly, the optical spectrum of a species with a given EPR signal can be deconvoluted from the contribution due to overlapping chromophores. Finally, because the optical transitions which are active in MCD may be strongly polarized, for example, along the molecular x and y axes, only the component of the ground state g-tensor perpendicular to these two axes, namely g_z, is detected optically. Likewise g_x is only detected via yz polarized transitions. Thus, directional information is obtained from a frozen glassy solution and the relative orientations of the optical transition moments of all the PROD active bands and the ground state g-tensor components are obtained.

The intense blue copper protein, azurin, is present in the bacterium *Pseudomonas aeruginosa*. It transfers electrons to the cytochrome c peroxidase. The detailed molecular structure of the site is known from Xray crystallographic work, (figure 2). The shape of the PROD spectrum detected via the 'blue' band at 625 mm is compared with that of the conventional EPR spectrum in figure 3. Only the g_z component of the g-tensor is detected optically showing that the optical transition is strongly polarized in the plane perpendicular to the z axis of the g-tensor. PROD spectroscopy has shown that the optical absorption bands of the Cu_A site in cytochrome c oxidase have very similar polarizations to those of azurin, indicating some structural similarities.

This is a new application of MCD spectroscopy to proteins. It promises to provide a method of mapping out the detailed electronic and molecular structure of a metal centre within a protein. The ability to determine relative orientations is an important advance and complements the data obtained from EXAFS studies in which the angular information is totally lacking.

SERC has supported this work generously. Assistance has also been given by the Royal Society.

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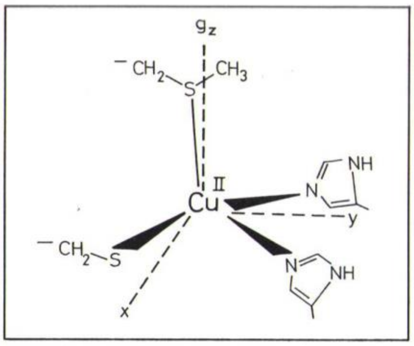


Figure 2: The structure of the copper centre in the 'blue' copper proteins, Azurin and Plastocyanin as determined by crystallography. The intense blue colour of the cupric form of this protein arises from an optical charge-transfer process from the thiol of the cysteine residue and is polarized predominantly in the x,y plane. The direction of the g_z component of the g-tensor shown was determined by single-crystal electron paramagnetic resonance spectroscopy.

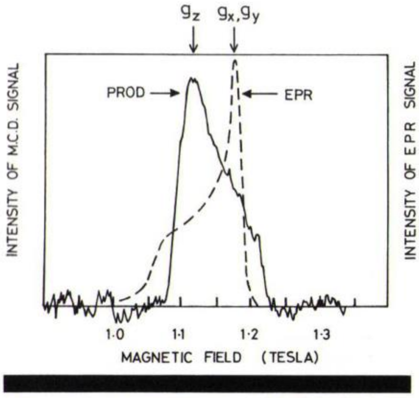


Figure 3: A comparison of the band shapes of the Q-band electron paramagnetic resonance spectrum and the PROD spectrum of Azurin.

FELLOWSHIPS 1985

This table shows the allocation, the number of applications and distribution of awards in 1985 between the various Fellowship schemes and the Special Replacement Scheme.

Type	Allocation	Applications	Awards
Senior	2	13	1
Advanced	12	80	12
Postdoctoral	49	209	49*
RS/SERC industrial	7	28	11†
Special replacement	5	17	4

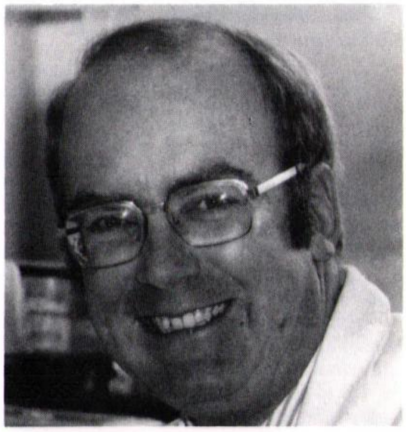
* In addition, nine awards tenable in Europe were taken over from the Royal Society. A further two awards were taken over from the Natural Environment Research Council for support under the NATO programme.

†One wholly supported by Royal Society.

Senior Fellowship for biochemist

The Senior Fellowship scheme is intended to enable a small number of outstanding academic scientists and engineers to devote all of their time to research free of restriction imposed by their normal duties.

This year one award was made, to **Dr C J Leaver** of Edinburgh University, for research in the field of plant molecular biology. Dr Leaver was born in 1942 and was educated at Imperial College, where he took a degree in botany. He was awarded a Fulbright scholarship in 1966 and, after a period with the (then) Agricultural Research Council Unit of Plant Physiology at Imperial College of Science and Technology, was appointed to the department of botany at Edinburgh University in 1969, where he is now a reader. He has made important contributions to our understanding of the molecular and biochemical basis of plant growth and differentiation, and has pioneered the use of biochemical techniques in the study of mitochondrial development in higher plants, with particular reference to the understanding of the basis of cytoplasmic male sterility in important crop plants such as maize and soyabean. In 1984 he received the Tate and Lyle Award made each year by the Phytochemical Society of Europe and given to the European investigator judged to have made the most important contribution to plant biochemistry in the previous five years. He will now devote his time to further studies of the molecular genetics of plant mitochondria which could provide an important basis for future applications in plant breeding and agriculture.



Dr C J Leaver

Industrial fellowships

Royal Society/SERC Industrial Fellowships are awarded so that scientists, engineers and mathematicians can move from academic life into industry or *vice versa.* The welcome increase in awareness of the scheme, in both the academic and industrial worlds, has produced a significant increase in the number of high quality applications for awards. In 1985, 28 applications for awards were received, compared with 13 in 1984 and 10 in 1983. To date awards have been made in fields such as industrial production processes, laser techniques, optical fibres and robotics.

Since its introduction in 1980 the scope of the scheme has been widened to include candidates working in an organisation in the public service as well as those holding a tenured post in universities or polytechnics or employed in an industrial organisation.

For 1985, fellowships have been awarded to the following:

Dr K W J Barnham (Imperial College) to Philips Research Laboratories;
A A Collie (Turnright Controls Ltd) to Portsmouth Polytechnic;
Dr B Fox (Queen's University of Belfast) to Northern Ireland Electricity Service;
I A R Galer (Loughborough University) to D C A Design Ltd;
Dr I Gladwell (Manchester University) to Numerical Algorithms Group Ltd;
Dr T W Hart (May & Baker Ltd) to University College London;
Dr R A Jewell (Binnie and Partners) to Oxford University;
D W Newton (Birmingham University) to Smiths' Industries;
D G E Smith (Scott, Wilson, Kirkpatrick & Partners) to Warwick University;
Dr R E Thurstans (Leicester Polytechnic) to V G Scientific Ltd;
Professor D R Wilson (Polytechnic of Central London) to IBM plc.

Further information about the scheme can be obtained by contacting Dr Peter Wakely at The Mount, Cosby, Leicestershire, LE9 5SH, telephone Leicester (0533) 863255, or Mr A J Hurst, Fellowships Section, SERC Central Office, Swindon, (ext 2352).

Part-time fellowships

It is believed by SERC that involvement in research at academic institutions should not be limited to those whose careers have been confined to academic pursuits. To this end some of the regulations applying to fellowships have been changed to make it possible for an award to be held on a part-time basis. This is intended, for instance, to assist women whose academic careers have been and are still interrupted by family commitments, and industrial employees who wish to benefit from experience in academic research while still maintaining contact with their employment.

A leaflet outlining the various ways in which SERC can support part-time and returning appointments, including fellowships, can be obtained from the Fellowships Section, SERC Central Office, Swindon (ext 2206).

RESEARCH GRANTS, POSTGRADUATE STUDENTSHIPS AND FELLOWSHIPS:

Changes in arrangements covering exploitation

On 14 May 1985, the Secretary of State for Education and Science, the Rt Hon Sir Keith Joseph MP, announced to the House of Commons the revised arrangements for exploitation of Research Council-funded inventions after the removal of the British Technology Group's right of first refusal of such inventions. In the light of the announcement, Sir John Kingman FRS, Chairman of SERC, wrote on behalf of the five Research Councils to Vice-Chancellors and Principals of universities inviting them to propose arrangements under which they would wish to exploit inventions. On 22 May 1985, SERC's Finance Officer wrote to universities (Letter RG 4/85) detailing the interim arrangements for research grants while they consider what arrangements they wish to propose. SERC studentships and fellowships are also affected by the announcement but in practice the impact of the changes on these awards is expected to be slight. Unless stated otherwise, the changes stipulated for research grants also apply to studentships and fellowships.

Aims

The Government's overall aims in the new arrangements are: *"to increase the exploitation of research funded by the Research Councils for the maximum benefit of the UK economy; to strengthen and improve exploitation through freer competition between exploiting agencies in the public and private sectors and in other ways; therefore to place responsibility and initiative for exploitation as fully as possible on researchers, their institutions and the Councils, consistent with other legal responsibilities; and to increase the incentive for researchers and their institutions by enabling them and the work they do to benefit from increased exploitation."*

Applicability

- The new arrangements are intended to apply to inventions identified on or after 14 May 1985.
- Only universities are included in the new provisions; they do not at this stage cover local education authority higher education institutions or Scottish central institutions.
- SERC standard, special and visiting fellowship research grants including those involving Teaching Company programmes are in general covered by the new arrangements. It is not intended at this stage to change the arrangements for CASE and industrial studentships, Royal Society/SERC industrial fellowships and cooperative research grants under which ownership of results passes to the industrial cooperating body although the Council is prepared to consider proposals for universities themselves to negotiate royalties with the industrial cooperating body. A number of other special arrangements exist including grants under the Alvey and Joint Opto-Electronic Research schemes, various cofunded programmes and grants for the Biotechnology Directorate's protein engineering programme, all of which remain subject to the existing grant conditions applicable to these schemes.

Interim arrangements

Proposals for exploiting individual inventions should be submitted to SERC for consideration. These should be addressed to Mr R G Tidmarsh in the Finance Division of SERC Central Office, Swindon. It is the intention to agree proposals wherever possible and within the principles laid down by the Government. Letter RG 4/85 of 22 May 1985 sets out the modified grant conditions governing exploitation during the interim period.

Submissions for approved arrangements

SERC expects to receive submissions from universities by early October 1985 giving details of their proposed exploitation arrangements. These submissions will be considered by a committee which will include representation from the Research Councils, the University Grants Committee, the Committee of Vice-Chancellors and Principals and the government departments concerned. Universities wishing to take advantage of the new arrangements and whose proposals are acceptable to the Committee will, in effect, be issued 'licences to exploit'. Some universities may wish to continue to act under the existing arrangements.

Enquiries

Any enquiries concerning the new arrangements should be addressed to Mr R G Tidmarsh, SERC Central Office, Swindon (ext 2179).

Some new publications from SERC

Future facilities for advanced research computing is a joint report by the Advisory Board for the Research Councils, the Computer Board for Universities and Research Councils and the University Grants Committee. Copies are available from Mr A G Brittain, Secretary's Department, SERC Central Office, Swindon (ext 2174).

Research in medical engineering: a review of projects supported by the Engineering Board of SERC, prepared by Professor D F Williams of Liverpool University, shows how basic and applied research is being used to assist in the industrial development of medical devices and instruments and hence to improve standards of health care. Copies may be obtained from the Materials Committee Secretariat at SERC Central Office, Swindon (ext 2124).

Process engineering research opportunities proposes a working strategy and priority areas for SERC support in this field. Copies are available from the Process Engineering Committee Secretariat at SERC Central Office, Swindon (ext 2400).

Synthetic membranes and their applications: a report commissioned by the Biotechnology Directorate, the Process Engineering Committee and the Chemistry Committee, by Professor P Meares of Exeter University. Copies are available from the Biotechnology Directorate at SERC Central Office, Swindon (ext 2310).

Biobulletin, the Biotechnology Directorate's twice-yearly newsletter, is available from the Directorate at SERC Central Office, Swindon (ext 2310).

Environment Committee annual report 1983-84: copies are available from the Committee Secretariat, SERC Central Office, Swindon (ext 2123).

Materials Committee annual report 1983-84: copies are available from the Committee Secretariat, SERC Central Office, Swindon (ext 2124).

Production Committee annual report 1983-84: copies are available from the ACME Directorate, SERC Central Office, Swindon (ext 2250).

Expert systems in manufacturing engineering and *Capture of existing drawings* are reports on workshops sponsored by the ACME Directorate. Copies are available from the Directorate at SERC Central Office, Swindon (ext 2250).

Royal Observatory, Edinburgh: a comprehensive publicity pack containing *Research and facilities 1985* and separate leaflets on each of the Observatory's chief projects; the UK/Netherlands Millimetre-wave Telescope, the UK Infrared Telescope, the UK Schmidt Telescope and the COSMOS measuring machine. Copies are available from the Observatory (telephone 031-667 3321).

Scanning electron microscope at Glasgow

With support from the Physics Committee an extended version of the VG Microscopes HB501 scanning transmission electron microscope has been installed in the Department of Natural Philosophy of Glasgow University. The microscope is designed to improve the analytical capabilities of this type of instrument and, in addition to the field emission source, has a double condenser lens system and three post specimen lenses to provide electron optical flexibility. One important aspect of the work to date has been the development of quantitative microanalysis by Xray and electron energy loss spectroscopies.

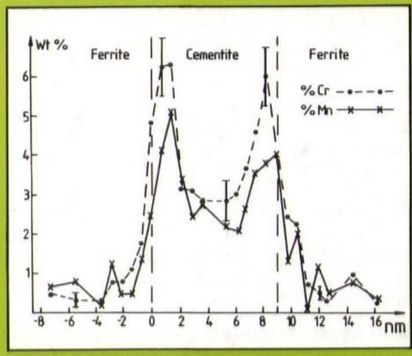


Figure 1: Composition profile for a cementite plate in a 20 nm thick area of a steel specimen.

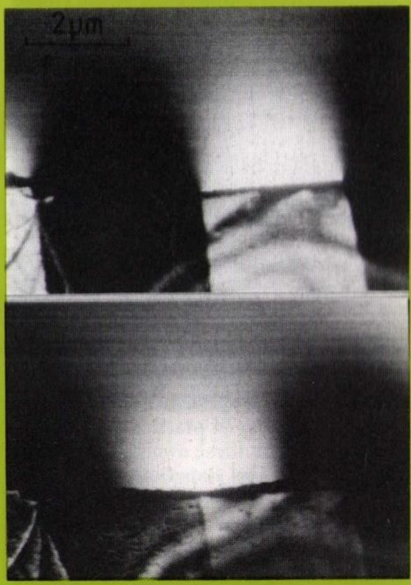


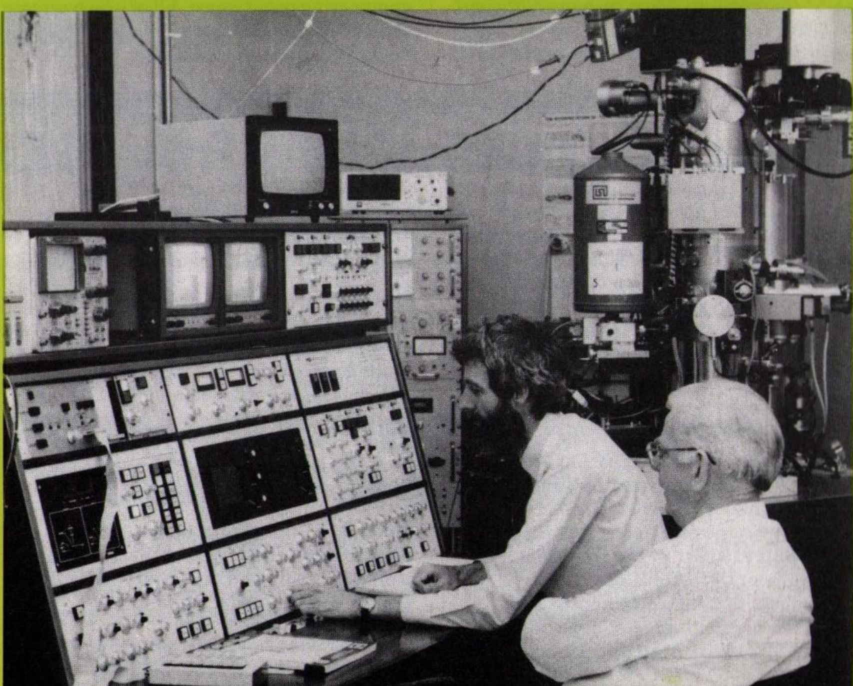
Figure 2: Magnetic induction distribution close to the edge of a cobalt foil. Contrast in the upper and lower figures relates to components of induction in a vertical and horizontal direction respectively.

Progress

Considerable progress has been made towards this goal and in addition the high spatial resolution capability of the HB501 for these techniques has been demonstrated (see figure 1). In addition to the normal bright and dark field imaging modes, effort has been put into developing the use of a quadrant detector for differential phase contrast; results from this technique have led to significant advances in our ability to determine the micromagnetic structure of ferromagnetic materials (see figure 2). Various diffraction facilities are available over a wide range of camera lengths. In microdiffraction, patterns from specimen areas down to about 1 nm can be displayed. The microscope is currently being used in the study of magnetic materials, amorphous semiconductors, semiconductor superlattices, precipitates in a variety of steels, superalloys, ceramics, pigments, catalysts and biological tissue.

Outside users

The microscope is available to outside users for approved projects. Experience has shown that there is an advantage if these are carried out in collaboration with one or more members of the Glasgow group, but independent use is not ruled out. Anyone interested in using the facility should in the first instance contact either Professor R P Ferrier or Dr J N Chapman at Glasgow on 041-339 8855. For information on how to apply for support to use the facility, contact Mr P N Burnell, SERC Central Office, Swindon (ext 2413).


Dr Chapman (left) and Professor Ferrier operating the Glasgow scanning transmission electron microscope.