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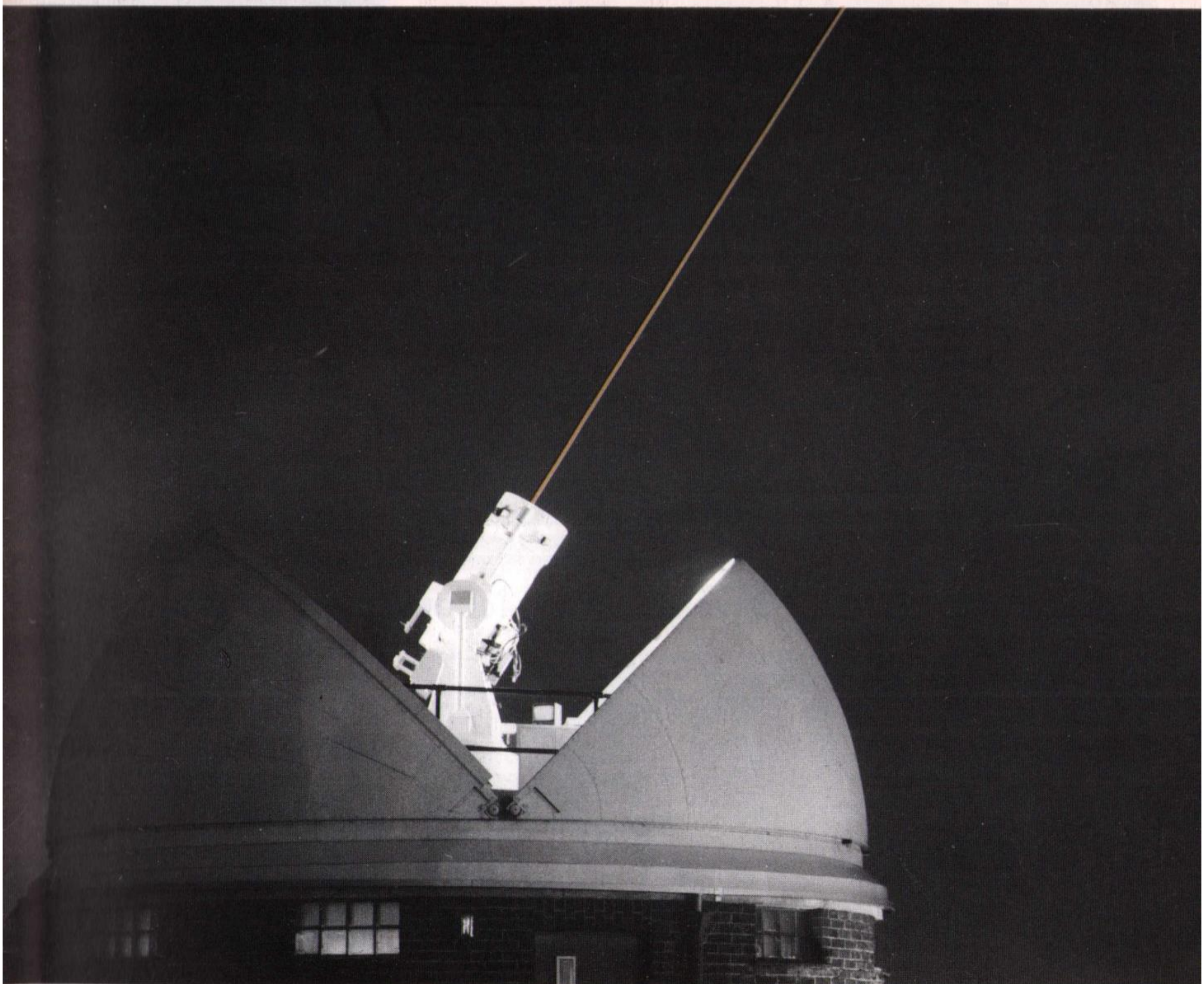

In this issue

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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 topics concerned with the policy, programmes and reports of SERC. SERC's *Annual Report* (available from HMSO bookshops) gives a full statement of current Council policies together with appendices on grants, awards, membership of committees and financial expenditure.**

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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Council commentary

Council in October met on two successive days: normal Council business being dealt with on the first, while the second was devoted to a wide ranging strategy discussion.

Space Review Committee

Council received the report of the committee set up under the chairmanship of Professor M H Richmond FRS to review the Council's space research programme. Council decided to return to the report after receiving the views of its Boards and Committees with interests in the field. The report was made available as a consultative document.

Fellowships and Awards for 1985

Council decided that it should provide the following numbers of Fellowships and Special Replacement Awards in 1985:

Postdoctoral Fellowships	60
Advanced Fellowships	12
Senior Fellowships	2
Industrial Fellowships	7
Special Replacement Awards	2

Major new grant

BIOTECHNOLOGY DIRECTORATE

A special four year rolling grant of £297,100 has been awarded to Dr C R Lowe, Director of the Biotechnology Centre at Cambridge University, for the development of biosensors for application in biotechnology.

New Process Engineering Committee

The Engineering Board has established a Process Engineering Committee, from 1 September 1984, chaired by Professor G S G Beveridge FEng of Strathclyde University. Its remit is: chemical engineering; polymer engineering; coal technology (see page 14); and parts of the Energy Committee's remit, including the cofunded programmes with the National Coal Board and the British Gas Corporation (see below). The possible inclusion of other aspects of process engineering, presently the responsibility of other Engineering Board commitees, within the remit of the new Committee will be discussed during the year.

Arrangements for energy research

The Energy Committee was established by SERC in the mid 1970s to advise it on energy policy, to take an overview of SERC-supported research related to energy and, where appropriate, to fund directly such research in the universities and polytechnics. The Committee has supported several directed programmes akin to the Specially Promoted Programmes run by other committees of the Engineering Board; these have included fusion technology, heat pumps and heavy ion fusion.

As part of a recent review, the Board noted that there was now an increased awareness of the importance of energy throughout the Council's boards and committees: more than 80% of support for energy-related research was through committees other than the Energy Committee. The Board concluded that there was no longer a need for a separate Energy Committee and that it should therefore be disbanded.

From September 1984, the Energy Committee's directed programmes have become the responsibility of either the Machines and Power or Process Engineering Committees. The Board emphasised that energy relevance would continue to be one of the criteria used in SERC decision making by its committees. It also agreed to re-establish an Energy Round Table to review the support given by SERC to energy-related research and to comment on balances and gaps.

Front cover picture

A time exposure of the SLR system in action at night. The beam is generated by frequency-doubling the output from a mode-locked Nd-YAG laser in the room below the telescope, and is emitted through a chain of mirrors and beam expanders which point it at the satellite. The larger receiving telescope, on the same mount, contains spatial and colour filters which discriminate against photons that have not made the round trip to the satellite. The photomultiplier and timer operate at the single photoelectron level.

See page 20

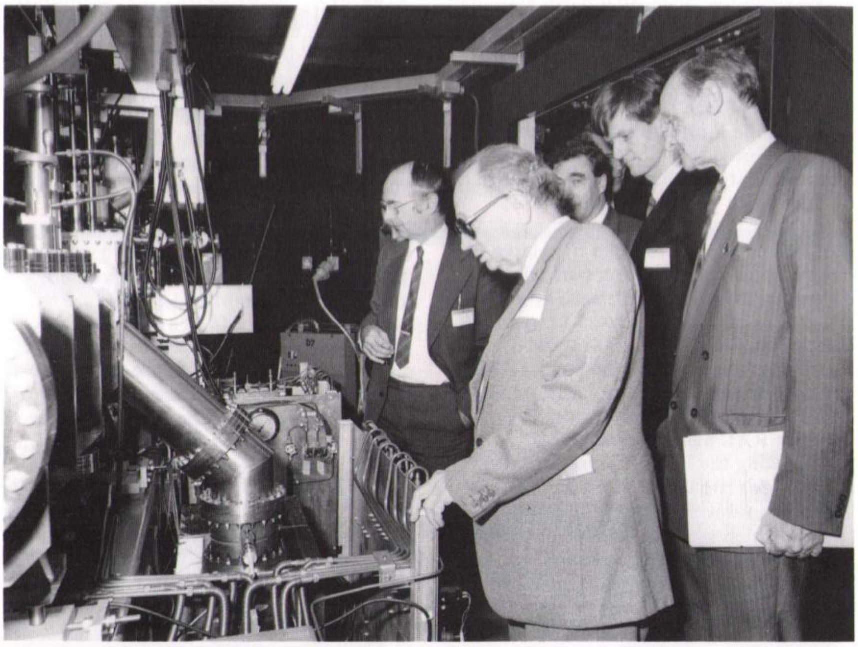
SERC—ZWO beam line on SRS

The SERC/ZWO beam line and its two experimental stations on the Synchrotron Radiation Source (SRS) were officially opened at Daresbury Laboratory on 1 November 1984. This beam line results from an agreement signed in December 1982 between SERC and the ZWO (the Netherlands Council for the Advancement of Pure Science). The new beam line transmits x-radiation from the SRS for use in x-ray absorption (EXAFS and XANES) and small-angle diffraction experiments. Dutch scientists are already making use of the SRS and the new line extends the facilities available to scientists of both countries.

At the opening ceremony, Professor Leslie Green (Director of Daresbury) in welcoming Professor Robert Van Lieshout (Director, ZWO) pointed out that in the short time since December 1982, a great deal had been achieved in the production and installation of the beam line and two experimental stations. "The Dutch scientists and engineers," he said, "have impressed us by the high quality of their work, and excellent relationships between engineers and scientists from both countries have been built up." The opening marked a new phase in the collaboration which would continue to strengthen the excellent relations which had been built up over the last two years. Professor Van Lieshout expressed his pleasure in opening the new line and reflected that, when the agreement was signed, it was clear from the enthusiasm of all involved that the project would be completed successfully. Indeed it had proved a very good example of how science organisation should work. Such collaborations were not only concerned with money and manpower but also with the skills, motivation and enthusiasm so essential for healthy scientific competition.

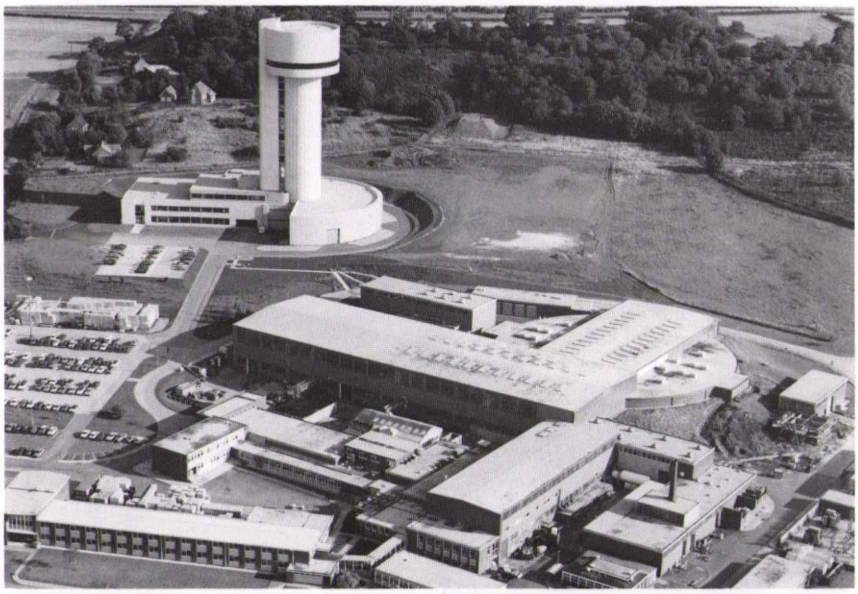
Representatives of both countries present at the ceremony looked forward with enthusiasm to experimental exploitation of the new facility.

For further information on the new facilities, please contact Dr S S Hasnain at Daresbury Laboratory: telephone (0925) 65000 ext 273.



Examining the EXAFS experimental station on the new beam line are (left to right): Dr D J Thompson (Head, SRS), Professor H de Waard (Chairman, Foundation of Fundamental Research, Netherlands), Professor Green, Dr J F Van der Veen (ZWO Synchrotron Radiation Committee) and Professor Van Lieshout.

Professor R Van Lieshout, Director of ZWO (left), presenting a plaque commemorating the completion of the new SERC/ZWO beam line at the SRS, to Professor L L Green, Director of Daresbury Laboratory.



Daresbury Laboratory from the air. The Synchrotron Radiation Source is in the low circular building to the right. Beam line 8, the SERC/ZWO line, emerges into the large experimental hall in the centre. (The tall tower houses the 20 MV Tandem Van der Graaff accelerator.)

DELPHI—third detector for LEP

This is the third in a series of articles about the experiments on LEP, the Large Electron-Positron collider currently under construction at CERN, in which British physicists will be taking part.

DELPHI is an acronym for DEtector for Lepton, Photon and Hadron Identification. Its purpose is to detect, identify and measure the products of the high-energy e^-e^+ collisions in LEP. A typical collision might produce 20 charged and 10 neutral particles. Of the three general-purpose detectors to be used initially with LEP, DELPHI is probably the most sophisticated and complex, providing three-dimensional measurements and high spatial resolution together with particle identification.

DELPHI is being developed by a large international collaboration comprising 37 groups from 16 countries. The three UK groups involved are from Liverpool University, Oxford University and Rutherford Appleton Laboratory (RAL) and they share major responsibilities for important parts of the detector. In addition RAL has designed and is constructing the large superconducting solenoid for the DELPHI collaboration. This solenoid will provide the magnetic field in which most of the detector will be immersed. The four main areas of UK involvement are briefly described here.

The superconducting solenoid

The solenoid is being designed and built by RAL under contract to CERN, acting as agent to the DELPHI collaboration. It is one of the biggest in the world, with an external diameter of 6.4 m, overall length of 7.4 m, a total weight of 83 tonnes, and will present a major problem in transporting to CERN. Use of helicopters or an airship have been mentioned but more conventional methods by road, sea and river are expected to be used.

The coil will be wound using an original technique developed at RAL, whereby the aluminium stabilised conductor is wound on the inside of a high-strength aluminium alloy cylinder. In addition to acting as the coil former, the cylinder supports the magnetic hoop pressure of 6 atmospheres. The conductor is indirectly cooled by 4.5 K liquid helium passing through tubes attached to the outside surface of the cylinder.

The superconducting solenoid, when assembled with the surrounding iron yoke, will produce a field of 1.2 Tesla over a total value of 145 m^3, for a total power consumption of 0.5 MW. Completion is due early in 1987 after assembly and test at RAL.

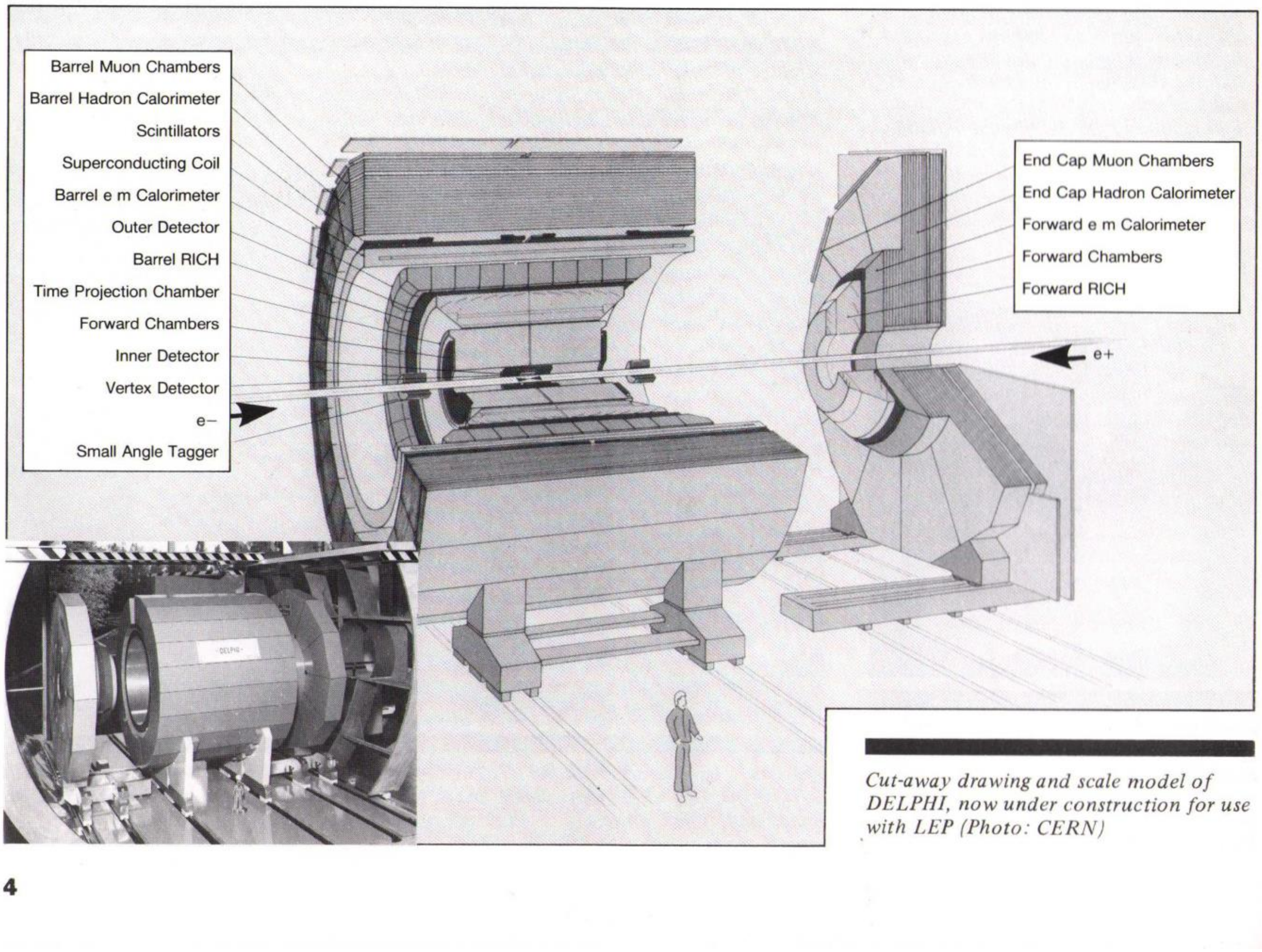
The outer detector

The outer detector consists of about 3000 square cross-section drift tubes forming a barrel of diameter about 4 m and 5 m in length. This barrel is concentric with the beam pipe and centred about the electron-positron collision point. The purpose of this detector is two-fold: it will provide both a fast trigger for the experiment and also extremely accurate track position information. Prototypes have been built and successfully tested. Final designs are now being prepared.

The outer detector is a joint Liverpool, RAL and Paris responsibility; the project is led by Dr Paul Booth of Liverpool University.

The muon chambers

These chambers consist of two (and in places three) layers of drift chambers designed to detect and identify muons.



Cut-away drawing and scale model of DELPHI, now under construction for use with LEP (Photo: CERN)

They are located in slots within the iron return yoke of the magnet and also outside it. The approximately 1900, 20 cm wide chambers will be able to locate the position of a muon to within a few millimetres.

The chambers are a joint Oxford University, Belgium and RAL project with Dr Alan Segar (Oxford) as project leader. About three-quarters of the chambers will be built and tested in the Nuclear Physics Laboratory in Oxford, where they were developed. They will then be transported to RAL to be bonded into planks before being shipped to CERN for installation. The remaining chambers (those on the end caps of the magnet) were designed and will be built by groups in Brussels and Mons.

Data acquisition system

The control, monitoring and collection of data from the more than 100,000 separate channels, which come from the complex detectors comprising DELPHI, will be implemented by use of a distributed computer system. In this system, each component is provided with its own minicomputer and slave microcomputers. Together with a large central system, these will all be linked by a local area network and a new high-speed data highway called FASTBUS. The mix of computers will span a whole spectrum of performance, ranging from mainframe power down to that of home microcomputers.

The RAL and Oxford University groups have played a leading role in the design of the system and are now involved in its implementation. In particular Dr John Barlow (RAL) is leading the group which has responsibility for the massive task of defining all aspects of the on-line software.

A new generation of detectors

The detectors to be used with the LEP machine are large and complex pieces of hardware, each with many sub-systems. The need for this size is partly due to the nature of colliding-beam machines: since the momenta of two particles colliding head on balance, the products of the collision can emerge in any direction, and so the whole of the solid angle round the collision point has to be surrounded by the detector.

Britain at CERN 1984

The biennial British trade exhibition at CERN was held in the second week of October 1984. A change in layout meant that it was possible to increase the number of exhibition stands by 50%, and industrial interest in the CERN market was amply demonstrated by the fact that all 36 stands were booked some months before the opening.

Another change this year was the introduction of a series of technical seminars on exhibitors' products. This innovation, too, was successful, and will be repeated next time.

As well as providing a shop window for British industry to engineers and buyers at CERN, the opportunity was taken to invite parties from local national laboratories, and from the Institut Laue-Langevin in Grenoble, in which the UK, via SERC, is a partner with France and Germany.

The exhibition was arranged by the trade association GAMBICA and the British Overseas Trade Board's CERN Task Force, which was set up to improve the UK export position at CERN and which includes representatives from SERC's Central Office and Rutherford Appleton Laboratory.

Mr Roy Trowbridge (left), Chairman of the CERN Task Force, with a representative from Pantak Ltd, welcomes Mr John Powell-Jones, HM Ambassador to Switzerland (right).

Nobel prize for CERN collider work

The 1984 Nobel Prize for Physics was awarded jointly to Professor Carlo Rubbia and Dr Simon Van der Meer, both of CERN, for work which was crucial to the discovery of the W and Z particles (see *SERC Bulletin,* Summer and Autumn 1983).

This joint award, to scientist and engineer, characterises the particle physics activity, in which innovations in advanced technology are necessary to implement proposals for research. It was Rubbia's idea – to use CERN's super proton synchrotron as a collider for protons and antiprotons – that allowed an energy level high enough to create the W and Z particles. It was Van der Meer's invention of 'stochastic cooling' that produced a beam of antiprotons with a long enough lifetime to make the proposal feasible. The W and Z particles are the carriers of the weak nuclear force, in the same way that electromagnetism is transmitted by the photon. The existence of the two W particles, one positively and one negatively charged, and a single, neutral Z, was predicted by the theory that links the weak and the electromagnetic forces, for which Glashow, Salam and Weinberg received the Nobel Prize for Physics in 1979.

All three particles were first detected by experiment UA1 at CERN, led by Rubbia. There is a strong British representation, from Birmingham University, Queen Mary College, London, and Rutherford Appleton Laboratory, in this large international collaboration that involves about 140 physicists. Dr Alan Astbury of RAL was Rubbia's co-spokesman for the UA1 collaboration until he took up a chair of physics in Canada in 1982.

The scientific significance of the discoveries is that they provide experimental proof of what had been a theory, and that this opens up the way to work that could 'unify' all four of the known forces in Nature – the exciting prospect of a single conceptual understanding of all forces and matter. Both prize-winners have paid tribute to the large number of people who made their achievements possible – fellow-members of the UA1 team, the CERN support staff, and the builders of the experimental detectors in the national laboratories.

The Oxford Enzyme Group

The Oxford Enzyme Group was formed in 1970 following a suggestion by Professor Sir Ewart Jones that chemists were poorly funded because they did not approach large problems in groups. He in turn had been stimulated by a suggestion at an SERC committee meeting that chemistry was really a cheap science in contrast to nuclear physics where large groups and large machines were involved. Chemistry did not need such substantial funding.

The Enzyme Group was formed after discussions by some 30 people from ten departments in Oxford covering chemistry and the biological sciences. It recognised that chemists and physicists might well provide the expensive tools needed to solve many biological questions but that they were without adequate biological knowledge. Many of the questions to be solved in biology are very complex both at the phenomenological and at the physical chemical levels. Examples are the nature of proteins (enzymes), the nature of biological machines, the problems of bio-energetics and membranes, the reading of DNA and differentiation. They cannot be solved by isolated small groups except by luck, since such groups will not command adequate funds for the necessary apparatus and people.

The problem of enzyme activity was chosen for study by us and, given the presence at Oxford of a fine x-ray diffraction department for the study of enzymes in crystals, major emphasis was placed on the development of solution studies by high resolution nuclear magnetic resonance (NMR). Professor Sir Rex Richards was elected as chairman and our first task – to convince SERC of our competence and that our choice of problem was worthy of financial help on a substantial scale – was managed with no hiccups but not without detailed enquiry.

The second task was to design the correct equipment. This step, taken after much consultation, led to the development of the 270MHz high resolution Fourier transform NMR spectrometer. Credit must be given here to the work of the two industrial companies Bruker Spectrospin and Oxford Instruments. They gambled on our scientific insight into what was needed. As a consequence they have profited greatly. There is no doubt that chemical and bio-chemical sciences world-wide have benefited. Large parts of chemistry and a good deal of biochemistry require modern versions of this instrumentation. For us this has been marvellous spin-off but our major objective was to solve a problem – the nature of proteins. In order to maintain individual identities within the Enzyme Group structure, different small groups chose their own enzyme for study but we all tried to relate to hydrolytic reactions especially of glycolysis.

Within the first five years the collaboration proved very successful. We developed a range of NMR approaches to protein structure, which make it possible to follow all aromatic and many aliphatic amino-acids in a protein (figure 1). It was possible to show using these NMR methods that an enzyme, such as lysozyme, was very similar in structure in solution to the picture given by Sir David Phillips and his group from crystallographic data. However two new facts emerged from the NMR data and the full significance of these facts is still under study since they throw quite a new light on proteins. First, individual

Figure 1

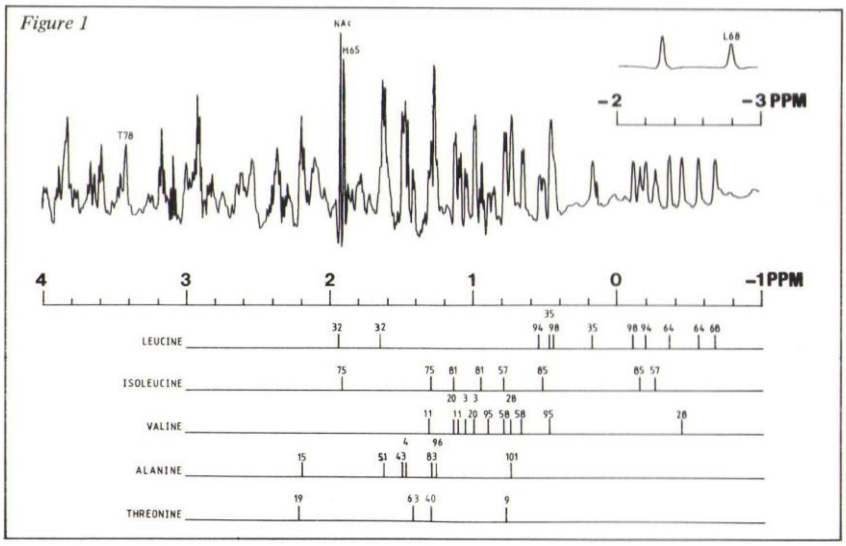


Figure 1: Part of the high resolution (470MHz) proton NMR spectrum of cytochrome c in solution showing the methyl resonances, all individually assigned, in a molecule of approximately 15,000 molecular weight. The NMR spectrum is a finger-print of the structure. Below the spectrum, a bar for each methyl group is labelled by the amino-acid number in the protein sequence, to represent the position of its resonances in the spectrum itself.

Figure 2

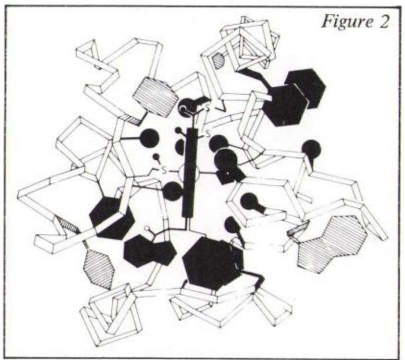


Figure 2: A mobility map of the interior of cytochrome c in solution deduced from NMR studies. The filled-in residues have very slow motions. The hatched residues (on the surface largely) move rapidly, flipping or flapping at rates greater than 10^3 per sec.

Figure 3

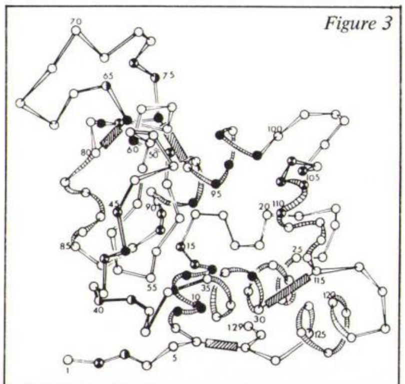


Figure 3: Outline of the structure of hen lysozyme from x-ray crystallography. Resonances of more than 40 of the 129 amino acid residues have been identified and assigned in the proton NMR spectrum in solution. Amongst the assigned resonances are many from amide protons and the rates at which the protons exchange with deuterons of D_2O solvent have been measured. The diagram shows different exchange rates:
● t½ greater than 60 days
◐ less than 1 hour
◑ 7 - 21 days. Open circles indicate NH of unknown rates.

side chains and even segments of a protein had controlled motion, often of high rate and sometimes of considerable amplitude (figures 2 and 3). Second, local interaction of a chemical at a site in a protein caused small changes over large regions of the structure. These observations were confirmed and studied later by crystallographic approaches. Both facts imply that a protein is not a very rigid object and the second fact indicates that despite this the energetics of its reactions were likely to involve 'directed' cooperativity deep inside the structure. An enzyme was not just a set of attacking groups correctly positioned on a rigid backbone but a dynamic cooperative reactant working in a cycle. The description of a catalyst as being unchanged in the overall reaction remains true of course but in a variety of complex ways the free energy of reaction of the catalytic steps involves changes in the protein catalyst.

The main people concerned with the development of high resolution NMR instrumentation in the Oxford Enzyme Group. From left to right: J Boyd, N Soffe, J D Campbell, R Porteous.

We were not really ready for these findings which have forced a reappraisal of protein (enzyme) function. We now realise that to understand protein activity we must know not only (1) the chemical sequence and (2) the physical structures but in addition (3) the (controlled) mobility in several states. If such tools as site specific mutagenesis are to be used properly it is essential to appreciate the limitations implied by our findings. All our subsequent work has been guided by the change in our basic knowledge which clearly invalidates a simple connection between any possible small-molecule homogeneous catalyst and enzymes. In a certain sense enzymes are types of heterogeneous catalysts but they are more subtle. The fitting of substrate to protein surface is no longer the fitting of a die in a mould or even of a key in a lock but it is more closely akin to the fit of a hand into a glove. Hand and glove then share continuous energy exchange over a large surface. Now the greatest advances from this new approach will be, we believe, in a much deeper understanding of biological systems. The evaluation of motion in proteins is the first step from the knowledge of static structures to the visualisation of purposeful dynamics in molecular machines. What we see in the isolated enzymes is the beginning of a study of coupling between energy input, its transduction say from electrical to mechanical to chemical energy, and the energy output in information transfer, in development of tension and in switching on or off particular activities, ie certain enzymes. The mobile segments may well also be the sites of antigenicity.

We have been able to give detailed descriptions of structure/mobility relationships of electron flow using cytochromes, of calcium-trigger action, and of kinases. Curiously the actual steps in reactions of the glycolytic enzymes still elude us. Maybe we look for too chemical a mechanism when the solution to the enzyme problem rests in physical strain assisted by binding energy and motion (much harder to detect) and only aided by chemical attack. Is this the real source of enzymic power?

We are now searching for ways in which to study biological organisation of complex enzymes which will make great demands on the ingenuity of us all since interactions between large molecules in biology cannot be represented by structures of isolated bits. It may be that the surfaces of proteins are not well represented by structures but should be illustrated by potential energy diagrams of mobile areas (figure 4).

During the course of our early work we also came across NMR methods for distinguishing mobile small molecules and mobile segments of larger more structured molecules. These observations led several of us to look at mobility in intact biological cells, organelles, and eventually in living animals and plants. Now there are three separate groups for these studies in Oxford but their origin lies in the potential developed within the Group. Here again there is potential spin-off in both medicine and agriculture.

SERC has supported this project on a handsome scale; comparable assistance has come from Oxford University, the Medical Research Council, the Wellcome Trust, the Abraham Trust, and the Wolfson Trust.

R J P Williams FRS
Napier Royal Society Research Professor at Oxford.

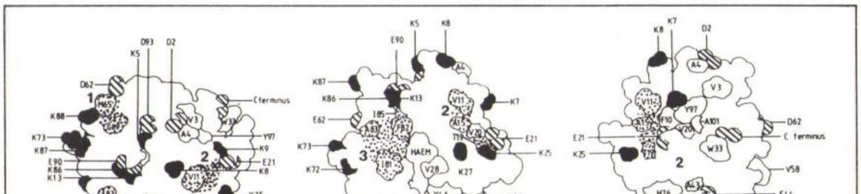


Figure 4: The surface of a protein cannot be represented by a structure. Instead, using NMR methods, different types of potential energy maps can be made. In the above map dotted areas illustrate the regions of high positive potential energy, discovered by effectively rolling a negatively charged ball, a chromium (III) hexocyanate ion, all over the protein surface. The relationship to positive charges (filled-in) and negative charges (striped) of the protein is shown.

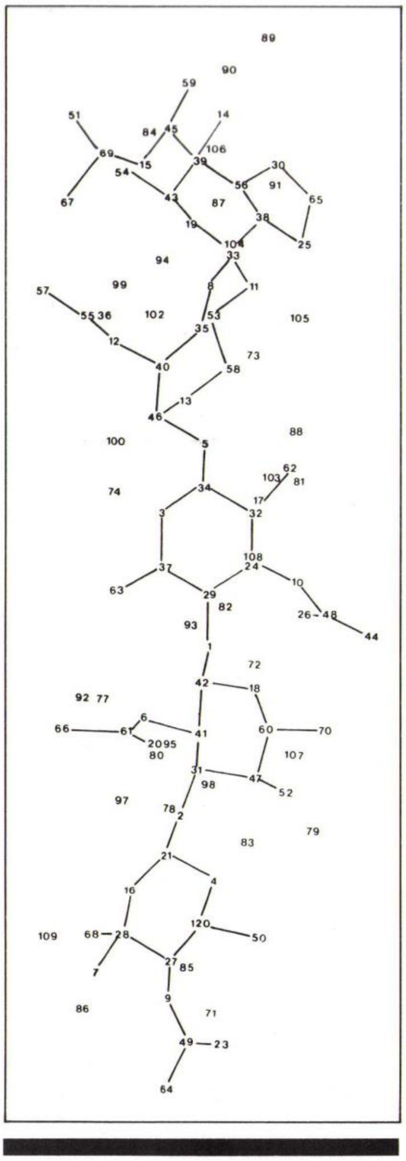
Oxford Enzyme Group members

The members of the Enzyme Group are drawn from many laboratories and departments at Oxford University:

Biochemistry Department
Botany Department
Clinical Biochemistry Department
Dyson Perrins Laboratory (organic chemistry)
Inorganic Chemistry Laboratory
Laboratory of Molecular Biophysics
Pathology Department
Physical Chemistry Department

Crystallography — direct methods at York

There are two stages in image formation – scattering by the object and recombination of the scattered radiation. X-rays can be scattered (diffracted) by a crystal, but with no lens available to recombine the scattered rays with their correct relative phases (that is with the peaks and troughs of their wave motions correctly superimposed), no physical image can be formed. Earliest attempts to solve crystal structures were by trial and error, where the calculated diffraction pattern was compared with that observed, much as is done today for surface structures by LEED (low energy electron diffraction).



A typical lineprinter output from MULTAN. The program gives more points than there are atoms. The user connects the points to form bonds with the help of printed tables giving bond lengths and angles.

Experimental measurements give the intensities of the scattered beams but not their relative phases and this constitutes *the phase problem in crystallography*. Beginning in 1948, theoretical work on the phase problem showed that, owing to physical constraints such as the positivity of electron density, there existed relationships between phases. This has led to procedures for determining sets of probable phases for the strongest diffracted beams; usually several plausible sets of phases are found and mathematical tests must be used to rank them in order of the probability of being correct.
With a set of phases available the action of a lens may be simulated and the electron density, and hence the atomic positions, in the crystal may be found.

The development of direct methods

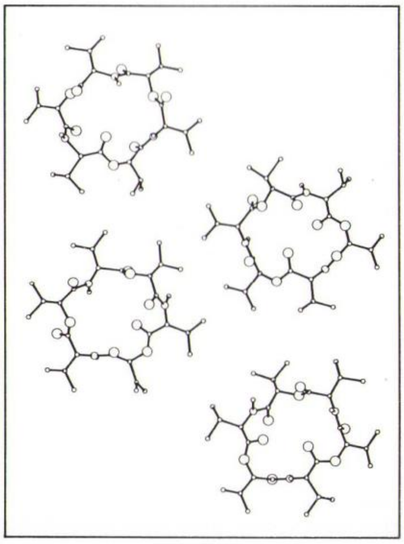
In 1963 Isabella and Jerome Karle in the USA introduced their so-called symbolic-addition procedure for solving structures and they were the first to solve non-centrosymmetric structures by what are now referred to as *direct methods*. The development of direct methods, which overcame some important drawbacks of the symbolic-addition procedure and were also capable of complete automation, began at York University in 1966. The aim was to produce a program which would run on any computer of modest size, which would have as input the absolute minimum of observed data and which, with minimal (ideally zero) intervention on the part of the user, would provide an easily-interpretable representation of the crystal structure. The program which emerged in 1971, MULTAN, has developed greatly in sophistication and power over the years. Currently about one half of all reported structures are solved by its use and it has been successful in solving molecular structures containing up to 200 independent non-hydrogen atoms. While user intervention is possible, the decision-making ability of the program is such that intervention is unnecessary or even undesirable; a default run will usually give the solution.

The output from MULTAN consists of favourable projections of the structure produced by a lineprinter. If only a fragment is found, then this may be recycled through the program until the complete structure is revealed.

Over the years procedures based on new mathematical concepts have been incorporated into a package which is still referred to by the generic term MULTAN, although it incorporates four different methods. With this armoury available, failures are very rare for structures with up to 100 independent atoms.

With the availability of four-circle diffractometers for automated data collection and of computer-based direct methods, structural crystallography has now become a routine tool for the chemist and finds wide application in academic and industrial research – for example, in the pharmaceutical industry. Current developments at York, in a well-developed state, promise to extend the range of direct methods to structures containing about 400 independent atoms. New ideas, still at an embryonic stage, offer the prospect of the *ab initio* solution of macromolecules – but that is still some way off.

Professor M M Woolfson FRS
Physics Department, York University



The structure of Enniatin B solved by MULTAN. The molecules are not related by crystallographic symmetry, so all the non-hydrogen atoms shown are independent.

Molecular electronics — the new dimension

Molecular electronics is the term used to describe a broad area of research which aims to use molecular materials to produce new or improved electronic devices. Several advantages are envisaged for molecular materials in device applications. They can offer chemical and biological specificity; they can be modified chemically in systematic ways; they can yield structures of very finely controllable dimensions; they can be processable at moderate temperatures. Such features can be exploited in various ways to modify existing devices or construct new ones.

Research on molecular electronics is of very wide scope and is inevitably interdisciplinary. It has three main aspects: the design and preparation of new molecular materials, the study and optimization of applicable properties, and the development of practical devices. These aspects are not independent, and one characteristic feature of research in this area is the synthesis of hybrid materials which combine the virtues and minimise the faults of the parent materials.

New materials and properties

Materials and properties of particular interest include:

□ Liquid crystals, less for their now familiar use in displays than for their potential use in switching and memory elements.

□ Langmuir-Blodgett films deposited from solution on to a solid substrate; with the natural molecular orientation within each monolayer, the control over molecular architecture, and the precise definition of thickness, these films are valuable model systems for fundamental research and their potential is being explored in applied areas such as ferroelectricity, electrooptics and lithography.

□ Polymeric photoconductors and semiconductors which can be doped to increase their response, yielding photocopying systems and novel storage battery materials which need contain no metal.

□ Organic metals and superconductors, of potential value in connecting active materials and conventional semiconducting substrates.

□ Materials which react in light or electron beams and permit microlithography with features approaching molecular dimensions.

□ Photochromic and electrochromic materials which change colour rapidly to produce stable high-density information storage systems, easily read and conveniently erasable.

□ Pyroelectric and piezoelectric materials useful in detectors and transducers such as the electret microphone.

□ Biological molecules that can be used as sensors when immobilized on a semiconductor substrate which monitors their specific response to a target species.

□ Electrooptic nonlinear optical materials which combine high response and stability useful in integrated optics and optoelectronics.

In October 1984 the Science and Engineering Boards jointly appointed a Molecular Electronics Advisory Group (MEAG) (as a successor to the Council's Discussion Group on Molecular Electronics). The Boards have asked the MEAG, under the chairmanship of Professor Gareth Roberts FRS (Durham University), to advise them on a strategy for the stimulation and support of molecular electronics research. Other members of the group are:

Dr W Barlow
ICI plc

Dr J Brettle
Plessey Research (Caswell)

Dr R Heckingbottom
British Telecom Research Laboratories

Professor A Ledwith
Pilkington Bros plc

Professor T J Lewis
University College of North Wales, Bangor

Dr R Perham FRS
Cambridge University

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Unilever Research (Colworth)

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University of Manchester Institute of Science and Technology

For further information, contact Mr D M Schildt, Secretary to the MEAG, SERC Central Office, Swindon (ext 2212).

□ Volatile organometallic species which can be decomposed thermally or optically in the vapour to deposit epitaxial layers of inorganic semiconductors having a well-defined composition and thickness.

Because molecular electronics encompasses such a wide area, different parts are at widely different stages of development towards practical devices. Some, such as organic photocopiers, are already available; others, such as electroluminescent structures with their response enhanced by coating with a Langmuir-Blodgett film, are under development; yet others, such as artificial neurons, are only at the conceptual or speculative stage. Progress requires effective collaboration between experts in biology, chemistry, physics and electronics. It also depends on effective mechanisms for technology transfer from the academic to the industrial environment.

The Molecular Electronics Discussion Group

In view of the potential and diversity of molecular electronics, SERC established in 1980 the Molecular Electronics Discussion Group, composed of academic and industrial scientists from a range of disciplines. This Group has discussed research objectives and how they might be pursued in academic and industrial laboratories, with working parties on the particular topics of Langmuir-Blodgett films, metal-organic chemical vapour deposition, and molecular self-organisation. The MEDG final report, recommending establishment of a smaller advisory group to identify areas of molecular electronics where SERC should undertake special initiatives, has now been submitted to the Science and Engineering Boards.

Interest in molecular electronics is widespread and growing. There have been workshops on molecular electronics devices in the USA in 1981 and 1983 and a new Journal of Molecular Electronics begins publication shortly. The UK is well placed to play a major role in the development of molecular electronics, though this may have to be in selected areas. The subject offers scope for both ingenious science and innovative technology in a wide range of disciplines.

Professor R W Munn
Department of Chemistry, University of Manchester Institute of Science and Technology

Research into electroactive polymers

A programme to stimulate research into electroactive polymers was launched by the Engineering Board's Materials Committee in September 1982 and the author was appointed part-time coordinator in April 1983 (*SERC Bulletin*, Vol 2 No 8, Summer 1983).

Reviewing the SPP after its first two years, it is clear that it is beginning to achieve the original aim of stimulating fundamental research into polymeric materials with novel electrical and optical properties for eventual application in new microelectronic, reprographic and photoelectric devices.

Up to November 1984, 27 projects to a total value of £794,000 had been funded specifically under the SPP. In addition, committees of the Science Board are beginning to support a number of projects within their own remits which underpin the aims of the SPP. The same is likely to become true of work supported by the Engineering Board's Information Engineering Committee through the Joint Optoelectronics Research Scheme (JOERS). The very interdisciplinary nature of the area and the increasing awareness of the importance of potential inputs from the various disciplines within both SERC and the scientific community at large is well appreciated. It is gratifying to note that the SPP has encouraged interdisciplinary collaboration within and between universities.

The number of ways in which electroactivity can be manifest and exploitable in polymeric systems is likely to grow significantly. The subject will be an important part of the expected development of molecular electronics over the next 10 to 20 years. The following examples of areas considered important and supported by the Materials Committee illustrate those areas which are being encouraged at present but, in a rapidly developing field, other equally important areas are likely to emerge.

Photo and electron beam resists

□ Photo and electron beam resist polymers are of key importance in the development of the next generation of microelectronic devices. The problem is to obtain good resolution coupled with sensitivity and will require a better understanding of the fundamental processes involved on which a set of criteria for good lithography might be based. Irradiation interactions, solvent action and plasma etching, substrate adhesion and, in some cases, planarising properties need to be studied in a fully collaborative way making use of the expertise in universities, industry and research establishments. Examples of work supported include the synthesis and characterisation of electron beam resists at Strathclyde; the synthesis of amphiphilic polymerisable compounds for mono- and multilayer resists at Liverpool and mass spectroscopic studies of the interactions of reactive gas plasmas with polymers at Aston.

Professor T J Lewis, the programme's coordinator

Liquid crystal polymers

□ Liquid crystal displays are a prominent part of present day electronic systems and the advent of new liquid crystal polymers has opened up fresh possibilities not only for the development of storage elements and improved chromicity but also for new electroactive device applications based on the interactions between polymer structure and mesogen groups. The UK is fortunate in having good sources of the new liquid crystal polymers but what is needed is a rapid and thorough evaluation and exploitation of them. Examples of work supported include the study of lateral order in thermotropic liquid crystals at Cambridge; the dielectric and electro-optical behaviour of novel liquid crystal side-chain polymers at Aberystwyth and the optical properties of thermochromic liquid crystals at Manchester. Interdisciplinary proposals to explore the electro-mechanical coupling possibilities of these materials and hence to develop novel transducers are to be encouraged.

Highly conductive polymers

□ The development of highly conductive (and perhaps superconductive) polymers is an obvious major thrust of any programme on electroactive polymers. There appear to be three major research pathways to this goal. The first requires synthetic chemistry to construct conjugated or cyclic polymers which may be doped to give controlled conductivity. Problems of stability and reactivity arise but the variety of systems that might be studied is very large. The second approach is to incorporate a charge transfer system within a polymer matrix to form a composite in which the polymer imparts stability both electrically and mechanically. Again, there are considerable possibilities for interplay between polymer and charge transfer systems. The third pathway is to attempt electropolymerisation at an electrode in an appropriate solvent. Again there is considerable scope for devising synthetic routes involving reduction or oxidation steps and for controlled doping. The electro-chemical route is important since it not only links naturally with studies of derivatised electrodes and interface phenomena in electrochemistry and bio-electrochemistry but also relates to the development of polymer electrolytes and light-weight battery applications.

The SPP supports a number of projects in this area, including the synthesis and characterisation of new conjugated polymers at Durham; new polymers based on metal dithiolene compounds at University College of North Wales, Bangor; synthesis and evaluation of high purity diacetylene polymers at Queen Mary College, London and of modified polypyrroles at Southampton; polymers exhibiting ionic conductivity at Leeds; and polymer defect levels at Cambridge and at Exeter.

Workshops

Another important activity has been the organisation of workshop meetings aimed at highlighting and stimulating aspects of the electroactive polymer programme. Each meeting attempted to balance industrial and academic interests and to define the key areas where SERC support would be most valuable.

The first one, on **Polymers for advanced lithography**, was held in January 1983. The meeting considered a current urgent need within the UK electronics industry for reliable supplies of well-characterised and understood polymers for electron beam and x-ray lithography. Although, for the more widely used optical lithography, resist formulations are readily available from overseas suppliers, there are many problems arising from a poor understanding of the constituents and chemistry of the resist components. The workshop concentrated on outlining the many problems encountered by device manufacturers in fabricating integrated circuits of high resolution and of considering ways in which UK university and polytechnic scientists might be encouraged to collaborate in overcoming the problems.

The second workshop, on **Anisotropic conductance**, was held in March 1983. The meeting considered electronic transport in anisotropic conductors, encompassing both polymeric and non-polymeric materials. It sought to highlight current UK research and attempted to clarify future research needs and opportunities for multidisciplinary cooperation. This workshop also brought together academic and industrial scientists and achieved its aim of stimulating interest in anisotropic conductors, highlighting a number of areas of opportunity.

The third workshop, on **Materials for information storage**, was held in March 1984. Since materials for optical information storage can be polymeric or non-polymeric the workshop was planned to encompass both, since the dividing line is not a firm one. A notable feature of this workshop was that all the speakers provided good coverage of their subjects and took care to present their material at a level which would be generally appreciated by the highly interdisciplinary audience. This encouraged lively discussion and emphasised the concepts at a fundamental level. Underlying many of the speakers' comments and certainly appearing several times in discussion was the worrying problem of achieving and thereafter maintaining a world standing in an area where competition was intense and the margins for ultimate commercial success were small. It was agreed that long-term research, initiated in universities and encouraged by industry, would be the only way to lay a proper foundation for future UK success in such a fierce market.

Electroactivity in polymeric materials is likely to become increasingly important as interdisciplinary awareness of the possibilities grows. Grant applications are welcomed for research within the Specially Promoted Programme (which is not necessarily restricted to the topics mentioned). The authors would be happy to discusss proposals with prospective applicants at any stage.

Further information on the SPP can be obtained from the authors: Dr Milsom at SERC Central Office, Swindon (ext 2338) or Professor Lewis at the School of Electronic Engineering Science, University College of North Wales, Dean Street, Bangor, Gwynedd, LL57 1UT (telephone Bangor (0248) 351 151 ext 721).

Professor T J Lewis
Coordinator, Electroactive Polymers SPP

Dr S J Milsom
Secretary, Non-Metallics Subcommittee

Building research exhibition

Research supported by SERC's Building Subcommittee was highlighted at an exhibition held at the Great Hall of Reading University on 25 September 1984.

The exhibition, opened by Mr A J Egginton, SERC Director of Engineering, was mounted by 50 groups of grant-holders from 28 institutions, covering all areas supported by the Subcommittee. Particular emphasis was given to the work of two Specially Promoted Programmes – Energy in Buildings and Construction Management. Among the other areas covered were computer-aided building design, acoustics, building materials, maintenance and fire safety.

The aim of the exhibition was not only to bring together a major part of the research community to discuss their work but more importantly to illustrate the quality and versatility of the research to those outside the academic world.

During the day more than 200 people visited the exhibition, mostly from the building industry. They came from government departments and laboratories, local authorities, client organisations, major contractors, designers and architects. One senior partner of a large company said that he had only intended to spend an hour at the exhibition, but had ended up staying the whole day. The exhibitors also said they had benefited both by the opportunity to present their work and by the chance to relate research ideas to industry.

Mr Tony Egginton (left) discusses the UMIST display on the application of risk analysis to the management of engineering construction with Mr R W Hayes.

The Building Subcommittee sees the exhibition as having been a step forward in its efforts to disseminate and implement the results of research, and is hoping to organise similar events in the future.

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Building Subcommittee
Mr N L Williams
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Medical engineering research programme

The Medical Engineering Specially Promoted Programme (SPP) is an excellent example of SERC's policy for bringing the academic world and industry closer together in research on engineering and applied problems of national importance.

The objectives and remit of the medical engineering programme are:

☐ To bring to medicine, and hence to society in general, the benefits of advances in engineering and technology.

☐ To develop closer collaboration between the disciplines, both clinical and technological, resulting in the formation of strong, interdisciplinary research groups.

☐ To stimulate projects under the programme by the active encouragement of applications to SERC; to maintain close contact with groups participating in the programme and to give advice direct to investigators where appropriate, concerning, for example, collaboration with other workers in both academic and non-academic centres.

☐ To develop a framework for assessing grant applications and priorities for research and to disseminate results of the research.

☐ Whenever possible to encourage work that could lead to new industrial ventures in medical engineering and to take all appropriate steps to promote rapid exploitation of work carried out under the programme.

☐ To ensure coordination of SERC-supported research with corresponding activities or requirements of other bodies – particularly the Department of Health and Social Security (Scottish Home and Health Department in Scotland), the Medical Research Council, British Technology Group, the Department of Trade and Industry – and industry.

☐ To develop an improved and better informed view of the needs for trained men and women and the nature of the training they receive in medical engineering; to monitor the provision of education and training in medical engineering and to ensure that it matches as closely as possible the national requirement.

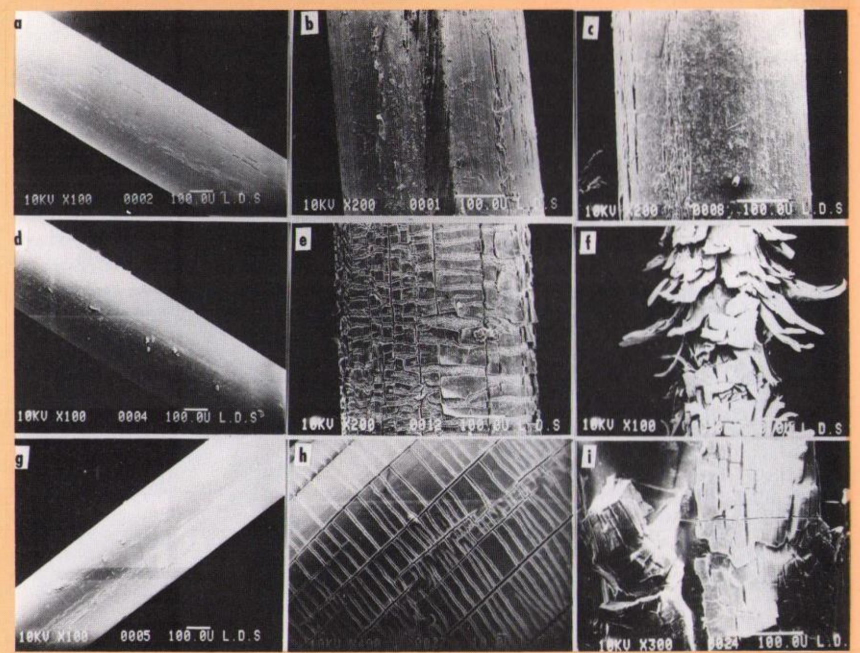
Planning and priorities

Because of the diverse nature of topics covered by the remit, a key element in the success of the medical engineering programme is the identification of priority research areas. The method used has been to divide the subject as a whole into discrete areas by means of discussions by groups of committee members, followed by further studies and meetings as required. The discrete areas chosen were: dental materials, internal prostheses, external aids, measurement and transducers, elderly/handicapped, surgical instruments, computing/control, and engineering principles in relation to the body. The next step was to arrange studies or meetings in each of these areas to enable a further selection to be made.

Meetings and workshops

Two meetings were held in 1978 and 1979: the first at Liverpool University on **Priorities in dental materials research** and the second at Leeds University on **Priorities for research on internal prostheses.** In each case, about 30 people attended, comprising scientists, clinicians, representatives from research councils, DHSS, and industry. The main objectives were to promote discussion on the present position and future trends and to formulate views on priorities.

In addition, six workshops have been held and the findings published or submitted for publication. The topics covered have been wide-ranging, consisting of **Incontinence, Body access, Pressure sores, Wound healing, Technical aids for the elderly/handicapped** and **Biosensors.** The meetings were attended by 30 to 40 people – materials scientists, engineers, medical personnel and representatives from the DHSS, MRC and industry – some experts and others new to the problems.



These scanning electron micrographs show the degradation of the absorbable suture material polydioxanone after exposure to an enzyme solution (esterase). The top line shows material irradiated to 5 Mrad, the second line at 10 Mrad and the bottom line at 20 Mrad. Duration of exposure to esterase increases from left to right. These studies form part of the biocompatibility work being undertaken by Professor D F Williams, Department of Dental Sciences, Liverpool University.

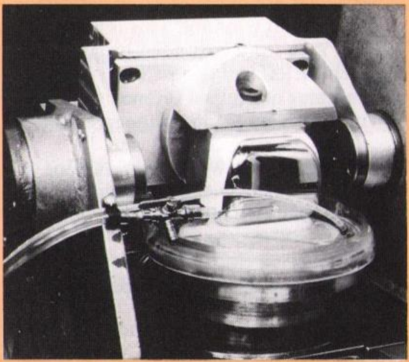
Awards made by SERC (1978-1984)

Area	Number of awards	Amount of awards (£000)	% of total (by value)
Biocompatibility	14	582.85	15.5
Adhesion	7	246.14	6.6
New materials	53	1477.13	39.3
Simulators	1	82.7	2.2
Membranes	4	128.5	3.4
Measurement and imaging	21	602.51	16.0
Analysis	1	46.2	1.2
Incontinence	2	87.5	2.3
Wound healing	2	82.34	2.2
Body access	0	0	0
Elderly/handicapped	8	233.62	6.2
Bedsores	0	0	0
Others	9	188.07	5.0
Totals	122	3757.56	99.9

As a result of these workshops and discussions within the Medical Engineering Subcommittee, a list of priorities has been prepared (see panel at right). The position on grants awarded by SERC to date is given in the table above. Over the past six years, about 40% of awards have been in new materials, 16% in measurement and imaging and 16% in biocompatibility studies. Examples of work supported under the programme are shown in the photographs.

Exploitation and industrial involvement

The development stage of new medical devices is expensive and involves toxicology *in vitro* and *in vivo* and production of prototypes under clean, controlled conditions. The rewards for success are high with good profit margins and excellent export potential if projects are carefully selected. Close collaboration is therefore being maintained with DHSS, BTG and DTI to promote development and commercialisation of inventions made within the programme.



Knee joint simulator designed and built at the Department of Mechanical Engineering, Leeds University on a research grant to Professor D Dowson. A Freeman-Swanson knee joint is shown under test. The metallic femoral component and polymeric tibial component articulate in a manner similar to that experienced in the knee.

Many grants awarded by the subcommittee have some measure of industrial involvement ranging from direct participation to the provision of materials and equipment. An example of this industrial involvement lies in the provision of new materials which offer the possibility of improved prosthetic joints and dental implants with extended life. The DTI, DHSS and SERC have collaborated in a programme to establish a clean manufacturing facility, develop medical grade ceramic and determine its properties, and test its suitability for applications in prostheses. Leeds University, the Royal National Orthopaedic Hospital and Imperial College, London, are collaborating in this development.

Education and training

Although biomaterials are included in a number of MSc courses in bioengineering and related subjects, there has been no specific course aimed primarily at biomaterials. Leeds and Liverpool Universities have organised a joint two-week course in biomaterials, aimed at new postgraduates and recruits to industry, which ran successfully in 1982 and 1984. The topics covered included the structure and properties of materials, clinical applications and the principles of biocompatibility.

Further information on the medical engineering programme can be obtained from the Secretary, Ms J S Williams, at SERC Central Office, Swindon (ext 2110), or from the author at 10 Warren Court, Frodsham, Warrington, WA6 6EN (telephone Frodsham (0928) 31511) who will be pleased to help in the preparation of proposals and advise on their suitability for the programme.

Dr E A Mason
Medical Engineering Coordinator

Priorities of the Medical Engineering Subcommittee

Biocompatibility Basic studies of the physics and chemical structure of biomaterials and the relationship to biocompatibility, including studies of the surface characteristics of implant performance.

Adhesion Basic studies of adhesion phenomena between living tissue and synthetic materials and studies of adhesion in specific situations in dentistry, implants, and external devices.

New materials Development of improved, natural, and synthetic new materials such as organic, inorganic and organometallic polymers, ceramics, metals and composites, for use in dentistry, internal prostheses, pharmacological preparations and external aids, especially those which match closely the characteristics of natural tissue and including studies of biological effects and key properties such as corrosion, wear, fatigue, and brittle fracture.

Simulators Development of improved simulators and animal models for testing orthopaedic and cardiovascular implants, and provision of adequate facilities on a national scale for testing and teaching purposes.

Membranes Studies and development of novel membrane systems for use in skin replacement, dialysis and life support systems.

Measurement and imaging Development of novel low-cost devices for measurement and imaging in medicine, especially transducers, NMR, ultrasound, biosensors and lasers.

Analysis Development of equipment for lower-cost analysis and measurement in the surgery and hospital.

Incontinence Development of aids for the incontinent, especially catheters, adhesives, seals, and collection and control devices, including implantable types.

Wound healing Studies of wound-healing process and development of novel sutures, dressings, and tissue adhesives.

Body access Development of new materials and devices for long term body access for purposes such as nutrition, dialysis, life support and neurological investigations.

Elderly Development of aids for the elderly and handicapped, especially studies of patient/device matching, bio-feedback, measurement systems, mobility aids, seating, and environmental control.

Bedsores Development of new materials and devices for the prevention and management of bedsores and studies of the process of formation.

Coal technology programme ends

The Specially Promoted Programme (SPP) in Coal Technology ended in August 1984, having run its allocated five-year span.

The objectives of the SPP were to support research aimed at improving the technologies required to win, transport, convert and utilise coal. It hoped to do this by encouraging academic departments not normally associated with the area to use their expertise to study coal problems, and also by promoting closer collaboration between the universities and the relevant industries. Achievement of these aims has been greater in some areas than in others. It is certainly true that researchers from many disciplines have been brought into the programme: apart from the departments traditionally associated with coal – mining engineering, mechanical engineering and perhaps chemical engineering – departments such as control, instrumentation, metallurgy, chemistry and microbiology have contributed. Much of this diversity has been achieved by organising meetings on various topics with a wide range of participants, and through the efforts of the coordinator, Mr Jack Launder. The promotional meetings covered coal winning, mining chains, hot gas cleaning, coal hydrogenation, coal chemistry and coal combustion.

During the period of the Programme, more than 100 research grants were made to a value of £4.2 million, some two-thirds of these to coal utilisation and one-third to coal winning. Within coal utilisation, combustion was the major activity, accounting for over half the funding. In this area two national facilities have been provided: the first, at Imperial College, London, is a fully instrumented cylindrical furnace constructed for research into improved design of pulverised coal-fired furnaces. This was built primarily for Dr F Lockwood's research programme but could be made available to other researchers. The second facility, provided at SERC's Rutherford Appleton Laboratory (RAL), is a high pressure fluidised bed capable of burning coal at rates up to 5kg/hour at pressures up to 21 bar. The facility was designed by Professor J Davidson of Cambridge University and is used mainly by his group, but is also available to other researchers. (Enquiries should be made to Mr G Gallagher-Daggitt at RAL, telephone Abingdon (0235) 21900). The uniqueness of the facility is its ability to operate at high pressures on a laboratory scale. The Cambridge work is leading to a better understanding of the relative importance of diffusion and chemical reaction rate in controlling the fluidised combustion of coal chars and confirms earlier indications that at high pressures the bed becomes more effective as a chemical reactor. Other work using the facility relates to absorption of SO_2 and NO_2 relevant to pollution control.

A successful seminar on coal chemistry held in October 1983 led to several good proposals in this area. It had been felt that there was a dearth of work on understanding the chemical and physical properties of coal and the seminar aimed to encourage more interest. Examples of programmes now supported are an investigation at Queen Mary College, London, of metal complexes in coal which could provide information relevant to troublesome deposits arising during a hydrocracking process, and studies of novel reagents for coal extraction; more speculative work at Birkbeck College, London, aims to discover whether free radical reactions in coal dispersions in hydrogen-donar solvents can be initiated photochemically.

The major disappointment in the programme has been the relatively small proportion of work in coal winning. Although excellent work is being done by the Departments of Mining (which are few), particularly at Nottingham University, there has been less success than had been hoped in attracting other disciplines. Coal winning research, especially coal extraction, is very much a priority area for the National Coal Board (NCB); fractional savings in the cost of coal extraction have substantial effects on the costs of energy, and there is much scope for improvement. Not only is there scope in the efficiency of extraction and preparation, but also in safety and environmental aspects in the mine. Examples of areas where further work is required are in research into hard materials for cutting, jet-assisted cutting, underground robotics, reliability and design of mining machinery and environmental aspects such as methane emission and noise. No programmes have yet been supported in underground gasification but this is considered by the NCB to have an important long-term interest.

Although the SPP has ended, this does not mean that coal technology research has ended. There will be a continuing need for much work in this area and, now that a coordinated community has been formed, it is SERC's hope that the impetus will be maintained. Discussions with the academic community and the industry towards the end of the programme highlighted the importance of maintaining a focus and integral responsibility for coal technology within SERC at the end of the SPP, in order not to lose the benefit which had been gained from the coordination provided by the Programme. This focus is now provided by the newly formed Process Engineering Committee which is looking after the whole area of coal technology. Several members of the former Coal Technology Subcommittee are serving on the relevant Subcommittee of the Process Engineering Committee in order to maintain continuity. Proposals in all areas of coal technology are welcome, but in particular are encouraged in various aspects of coal winning. This is also the priority area for a cofunded programme between SERC and the NCB, by which programmes of mutual interest to the two organisations are jointly supported.

Contact Mr Stuart Ward, Secretary of the Process Engineering Committee, SERC Central Office, Swindon (ext 2101).

Regional brokerage scheme discontinued

In 1980 SERC launched an experimental regional brokers scheme with four brokers located in Guildford, Newcastle, Bristol and Cambridge. The main aim of the scheme was to improve industrial awareness of the various grant and award schemes run by SERC to promote academic-industrial collaboration. The scheme was reviewed in 1984 and the considerable achievements of the brokers were acknowledged. However the SERC was obliged to weigh the undoubted benefits of the scheme against the very considerable costs of expanding the scale of the operation to form a national network. Also a number of other bodies and agencies operating at the academic-industrial interface had grown up over recent years and this development to some extent lessened the need for SERC to operate its own separate scheme. It was therefore reluctantly decided to teminate the scheme from 31 August 1984.

Refining the strategy for biotechnology

The Biotechnology Directorate's broad aims are to develop the academic research base in biotechnology in order to underpin UK industry; to support a sufficient number of postgraduates in biotechnology, to meet the national need; and to encourage and foster close collaboration between the academic community and industry in biotechnology.

The strategy drawn up to meet these goals has been widely publicised (see for example *SERC Bulletin* Vol 2 No 8, Summer 1983), in particular the identification of priority areas in which the Directorate has been active in encouraging further research. However all good strategies need to be kept under review and this is especially true in such a rapidly developing field as biotechnology. Furthermore, given current limitations on funding, the Directorate believes that to be effective it must further refine its strategy so that it has sufficient resources to make significant advances in key areas. As a result of extensive, and continuing, discussions between academics and industrialists, the following revised strategy has emerged:

☐ Process engineering in biotechnology

This is an area in which we are particularly anxious to encourage novel proposals both in fermentation technology and in downstream processing. We have already made substantial awards to the Chemical Engineering Departments at Birmingham and Cambridge Universities and at University College London, and continue to welcome new proposals and are taking active measures to stimulate work on separation processes, in particular work on membrane separations and selective adsorbents, including affinity processes.

☐ Microbial physiology

The Directorate has already provided substantial support to set up a centre of expertise at Aberystwyth on anaerobic metabolism and at Warwick on microbial oxidation. Further funding of research programmes in this area is likely to be limited, although some support will continue to be available, particularly for studies of the physiology of cells in the environment of the reactor or in an immobilised state.

☐ Large-scale growth of plant and animal cells

Research programmes relating to animal cells have been developed at Birmingham and at Surrey, and studies of large-scale growth of plant cells at Sheffield and Edinburgh/UMIST. These programmes will be kept under review but, in the present financial circumstances, it is unlikely that significant funds will be available to support further work.

☐ Plant genetics and biochemistry

After extensive discussions, the Directorate, the Agricultural and Food Research Council and the Department of Trade and Industry have identified three priority areas in plant biotechnology: the tuning and use of vectors in plant genetic manipulation; the molecular biology/biochemistry of seed development/composition; pathogenecity and symbiosis. We particularly wish to encourage programmes in the first two areas.

☐ Recombinant DNA technology

Following a review by an academic/industrial working party, it was decided that in future resources could best be deployed to promote studies of gene expression in eukaryotic, and particularly mammalian, cells. The Directorate will continue to consider programmes involving expression in yeast although here emphasis will be given to work carried out in collaboration with industry. Given the availability of support through other channels, we do not intend in future to support programmes relating to gene expression in *E coli*.

☐ Biocatalysis

Our objective is to develop a programme with the long-term aim of 'custom building' proteins (eg enzymes) to meet particular requirements. In pursuit of this objective, we are seeking to establish a major programme in protein engineering cofunded with industry. Discussions are already taking place with a number of academic research groups and it is proposed to launch a programme in early 1985. We shall also continue to support work in other areas of biocatalysis, principally on immobilised cells and enzymes.

☐ Biosensors and bioelectronics

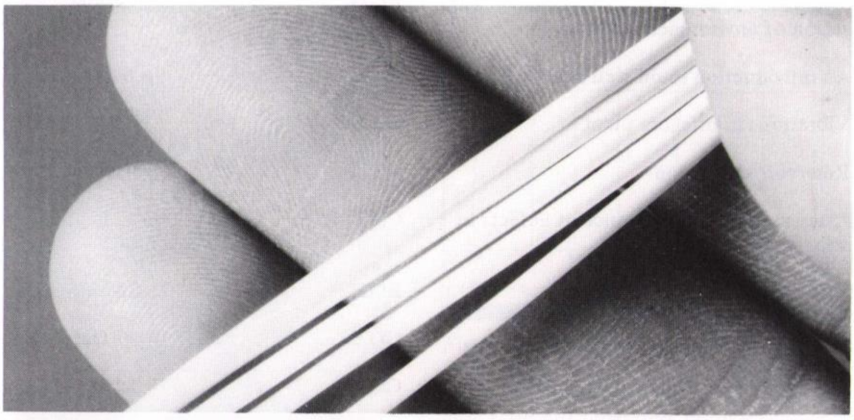
The Directorate is currently providing substantial support at Cambridge, Imperial College and Oxford/Cranfield. Our future support for this area will be coordinated with the Chemistry Committee's recent initiative on sensors.

To ensure that work supported in these sectors meets the real needs of UK industry, emphasis continues to be given to the provision of support through Cooperative Research Grants.

This is how the Directorate's priorities were seen at the end of 1984. They will be kept under continuing review; indeed a proportion of funds is earmarked to support new ideas which may be outside these priority areas. Meanwhile the SERC Biological Sciences Committee and Process Engineering Committee will continue to consider requests for support in other areas which underpin biotechnological applications.

The Directorate is also active in building up the necessary infrastructure for UK biotechnology, for example through provision of support for a sufficient number of postgraduates in biotechnology to meet national needs. In this context we commissioned a report on future manpower needs from the Institute of Manpower Studies and we now support four advanced courses on which a total of 30 advanced course studentships is provided. In addition in 1983/84 the Directorate provided 29 research studentships, for work on selected programmes in the priority areas, and awarded 28 CASE studentships.

For further information, contact Dr Doug Yarrow, SERC Central Office, Swindon (ext 2466).



Ultrafiltration membranes offer an alternative to expensive centrifugation for the recovery of precipitated protein. Shown here are hollow fibre membranes as used at University College London.

Marine technology short courses for 1985

Electronic instrumentation for the offshore industry	Strathclyde	February
Corrosion and corrosion prevention	CIT	11-14 February
Managing underwater inspection	Strathclyde	Feb/March
Oil and gas production systems	RGIT	25-29 March
Ocean waves for engineering design	Liverpool	25-29 March
Non-destructive testing	RGIT	25-29 March
Production platform process control simulation	RGIT	March/April
Platform superstructures – design and construction	City University	Spring
Introduction to underwater video systems	RGIT	April
The dynamic analysis of mooring systems	UCL	April
Materials and corrosion engineering	RGIT	April
Economics of ballast performance	Newcastle	April
Corrosion monitoring and inspection	UMIST	24-26 April
Flow induced vibrations	CIT	30 April-2 May
Management of contracts and projects	UMIST	May
Design to avoid failure offshore	CIT	13-16 May
Dynamic loading and response of offshore structures	CIT	13-17 May
Transient flow in pipes and duct systems	CIT	14-16 May
Geophysical signal processing	Strathclyde	June/July
Sea state and environmental data for the offshore industry – the contribution of remote sensing	Dundee	1-4 July
Mechanics of subsea equipment under the action of environmental forces	RGIT	September
An introduction to oil well drilling fluids	RGIT	2-6 September
Vibrations in offshore plant	RGIT	9-12 September
Reservoir simulation	RGIT	10-13 September
Assessment and significance of defects in structures	CIT	10-22 September
Offshore drilling operations	RGIT	16-20 September
Materials in offshore engineering	CIT	14-17 October
Offshore risk and its management	CIT	10-12 December

For further details, contact Mr A P Biles, Marine Technology Centre, School of Industrial Science, Cranfield Institute of Technology, Cranfield, Bedford MK43 0AL; telephone Bedford (0234) 750111 ext 2539, telex 825072 CITECH G.

PREST — developments in marine technology

The programme of Policy Research in Engineering, Science and Technology (PREST) in Manchester University's Department of Science and Technology Policy has established a 'club' of British companies for whom 'opportunity briefs' on new marine technologies are prepared. The 'club' is financed by members as diverse as John Brown Subsea, McAlpines, Wimpey, ICI and Marconi, and receives further funds from the Department of Trade and Industry and SERC's Marine Technology Directorate.

The 'club' is managed by the Underwater Engineering Group (UEG) under a steering committee consisting of representatives from the companies and other funding agencies. This committee determines, in consultation with the researchers, the work programme for each financial year. The topics covered in the current two-year programme range from **Ocean thermal energy conversion** to **Disposal of nuclear waste at sea** and from **Marine remote sensing** to **Artificial islands.**

Opportunities and benefits

The reports on these topics summarise the current situation in each area and evaluate likely future developments taking into account economic, political, legal and technical considerations. Specifically an attempt is made to point out opportunities that might arise for member companies, both directly and indirectly. Wherever possible these opportunities are quantified as technoeconomic targets.

The initial impetus to establish this users' group arose from the Marine Technology Directorate applying its criterion of industrial relevance to the programmes that it funds. For researchers working on the policy side of technology in universities, the demonstration of industrial interest poses a problem very different from those working on the hardware side. The model established by PREST has proved to be mutually beneficial to university and industry. The PREST team has benefited from looking at technology forecasting and assessment through the eyes of industry, and the fact that the club is expanding indicates industry's evaluation of its worth.

Further information may be obtained from the Project Coordinator, Daniel Stagnie, at The University, Oxford Road, MANCHESTER M13 9PL (telephone 061-273 7121, ext 5054/5060).

Filtering out the flaws

The Polymer Engineering Directorate has supported a wide range of research projects to overcome specific problems faced by industry. Here we feature a project carried out at Brunel University.

The use of metal separators and hopper magnets to remove both granules containing unwanted metallic impurities and metal particles themselves prior to processing testifies to the possibility of such flaws becoming incorporated into plastics feedstocks. These two techniques for removing flaws are limited in three ways:

☐ They only remove metallic particles, allowing other flaws and fibres through.

☐ The size of the particles they remove is limited; metallic separators, for instance, are at best capable of removing only metal particles larger than 200μm (0.2mm).

☐ They remove the flaws only from the feedstock in the hopper, but the wear of screws in barrels can create metallic flaws during processing, and these will progress into the final product.

To overcome these limitations, melt filtration is common in extrusion via the use of screen packs, which typically filter melts to 120 to 150μm. However, for certain plastics products, such as fibres and thin films (particularly those used for their optical and electrical properties), it is desirable, and in many cases necessary, to remove particles smaller than 100μm. Equipment is available for this, through a UK company, Process Developments Ltd, a recognised world leader in the design and construction of units capable of filtering plastics melts to less than 20μm.

It is now becoming apparent that this technique of fine melt filtration may have application to other plastics products, one such area being with polyethylene pressure pipe. The reason is that such pipes can fail by the slow, controlled propagation of a crack, which has been observed to initiate from included flaws (see figure 1). A fracture-mechanics-based analysis predicts that the strength of the pipe (measured as the lifetime) decreases with increasing flaw size, so that reducing flaw size via fine melt filtration should improve performance. A programme of experimental work was recently completed at Brunel University by Professor M Bevis and Dr J Bowman of the Department of Materials Technology, to investigate if flaw size did influence the performance of two types of polyethylene pipe – a high density copolymer pipe and gas pipe extruded from the BP Chemicals material Rigidex 002-40. This effect of flaw size was investigated by purposely adding flaws and filtering the metal to different degrees. The project was supported by the Polymer Engineering Directorate and four organizations, BP Chemicals Ltd, British Gas Corporation, Process Developments Ltd and Wavin Plastics Ltd.

In the case of the high density polyethylene (HDPE)/copolymer pipe, it is clear from figure 2 that fine melt filtration, using the Autoscreen from Process Developments (45μm filtering), improves the performance of the pipe when compared to pipe filtered with a standard stationary screen pack (150μm). Furthermore, the addition of particles reduced the lifetime at any given stress. It is thus clear that, with polyethylene pipe materials similar to the HDPE copolymer, it is important to filter the melt prior to the extrusion of pipe and that, if the melt is fine-filtered, the performance is enhanced compared to the standard screen pack.

With reference to the Rigidex 002-40 pipe, particles of aluminium (250-300)μm and glass spheres (100-200)μm in diameter were purposely added to the feedstock of material producing 63mm diameter pipe. These pipes were subsequently tested at 80°C and 9.3 bar gauge internal pressure and no failures were reported after 2000 hrs for the aluminium particles and 10,500 hrs for the glass spheres. The Rigidex 002-40 pipe grade polyethylene is thus more tolerant of large included flaws, and this demonstrates the strength of the pipe systems in use using this resin. However, filtration should still be undertaken even with these materials, since in service the pipe is subjected to more complex loadings than the simple internal pressurization of the stress rupture test.

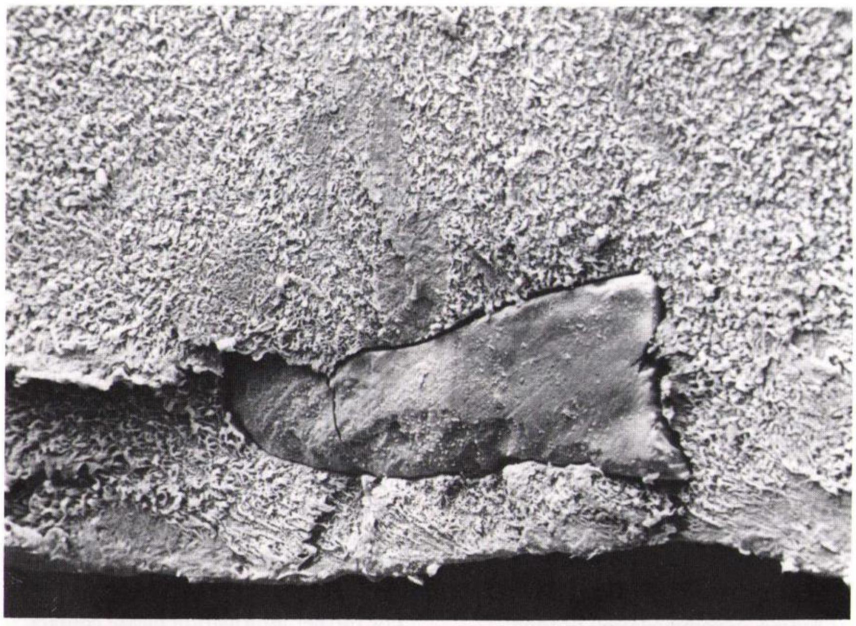


Figure 1: Example of a particle that initiated the fracture of a polyethylene pipe.

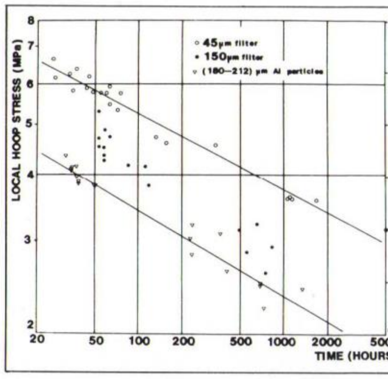


Figure 2: Brittle failure region of the stress rupture curves for three forms of polyethylene pipe extruded from the base resin but separately filtered to 150 and 45 μm and with (180-212)μm aluminium particles added. The higher up the curve, the better the performance of the pipe.

Distributed Computing Systems Programme 1977—84

SERC's Distributed Computing Systems Programme (DCS) terminated on 6 September 1984. The programme was the first (and so far only) Specially Promoted Programme in computer science to be launched by the Engineering Board. During the course of the programme 126 research grants were awarded to 26 institutions. The total funding received by the programme was around £8 million.

DCS was a coordinated research programme, the Academic Coordinator being drawn from SERC's Rutherford Appleton Laboratory and the part-time Industrial Coordinator from industry. Coordination has led to the creation of a strong cohesive research community and the establishment of new research groups. DCS has also enabled a number of young researchers to become established faster than would otherwise be possible.

The programme has achieved technical results of the highest quality, both in theoretical aspects of distributed computing and the practical construction of distributed systems.

The programme terminated with a conference at Sussex University. Two books have been published containing the major research results: the first, *Distributed computing,* edited by F B Chambers, D A Duce and G P Jones (Academic Press), aims to give a grounding in each of the main themes emerging from DCS – dataflow, declarative languages and architectures, loosely-coupled systems, closely-coupled systems and modelling and verifying concurrent systems; the second, *Distributed Computing Systems Programme,* edited by D A Duce (Peter Peregrinus Ltd), contains the papers presented at the conference, which include both reviews of particular areas and results of specific projects.

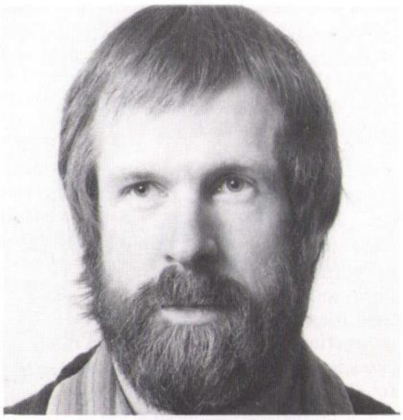
Information technology fellowships

Special IT Fellowships at a senior level have been awarded to **Professor R M Burstall** and **Professor M S Paterson.**

Professor Burstall has been associated with Edinburgh University since 1964. For some years he worked in the various Artificial Intelligence groups, his interest in heuristics and combinatorial search diversifying into mechanised logic and, for a while, robotics. In this time major achievements included the design, with Popplestone, of the POP-2 programming language and leading the team which, in 1973, programmed the 'Freddy' assembly robot. Increasingly however his interest has been in the application of mathematical methods to computing and particularly in the problem of developing programs in a systematic and reliable manner. In this connection, fruitful collaborations have led to the development of the specification language Clear, the programming language Hope, and Sakura, a language for VLSI simulation. Professor Burstall will spend the period of his award on two related topics; trying to express the mathematical structure of large programs and their developments in order to tame their complexity; and exploiting connections between the semantics of programming languages and those of natural languages.

Professor R M Burstall

Professor Paterson has, since 1971, been on the staff of the Department of Computer Science at Warwick University, spending some of that time as a visiting Professor at various USA universities and institutes, including Stanford and the Massachusetts Institute of Technology. Professor Paterson is a leading expert in the UK on the subject of computational complexity theory, which is characterised by a concern for quantitative information on the difficulty of computational tasks. This involves a combination of the skills of a careful programmer for the detailed design and analysis of algorithms for practical applications, and those of a pure mathematician to provide abstract theorems capturing some aspects of computation. Professor Paterson will spend the period of his fellowship in furthering this research, concentrating on three important areas, namely the circuit complexity of Boolean functions, matrix multiplication algorithms and the design of sorting networks. These raise difficult and highly theoretical problems, but any progress made would have wider pratical importance. Professor Paterson plans to take up his fellowship on 1 April 1985.



Professor M S Paterson

SERC graduate schools

The Graduate Schools programme is designed to encourage PhD science and technology students to consider the wide range of jobs that exist outside academic research. The Schools try to illustrate the kind of problems encountered by people working in industry and government and how their intellectual ability can help solve them.

Graduate Schools run for five days. All students in receipt of an SERC research studentship are encouraged to attend a Graduate School and there is no charge for tuition, accommodation or food. Students not holding an SERC award are also welcome to apply but would be expected to pay a fee of £285.

The Schools are rated very highly by students, almost 9000 of whom have attended Graduate Schools since they started in 1968. It is therefore worrying that a number of students have reported that their supervisors and heads of department did not know about Graduate Schools. We hope that all supervisors will encourage their SERC research students to attend the Schools.

For further information please contact: Mrs Jacky McMillan, SERC Central Office, Swindon (ext 2153).

SERC enquiry points

To make it easier to find the right person when you telephone our administrative offices in Swindon (or London), we are updating our list of key contact points. Except where otherwise stated, all extension numbers are at SERC Central Office, telephone Swindon (0793) 26222.

ASTRONOMY, SPACE & RADIO DIVISION

Solar, ionospheric magnetospheric and middle atmosphere physics, lunar and planetary sciences, remote sensing aeronomy	Mrs C A H Coates ext 2317
Radio, millimetre, x-ray, cosmic and heavy particle astronomy	Dr J H Price ext 2265
Optical, infrared and ultraviolet astronomy	Dr S M Mellows ext 2417
European Space Agency and remote sensing	Ms C A Iddon ext 2320 Miss C Armstrong ext 2367
PATT awards	Mr V M Osgood ext 2418
Research grants	Mr P G White ext 2359
Studentships and fellowships	Miss C M Reason ext 2419
Computing	Mr J E Morgan ext 2383

ENGINEERING DIVISION

Medical engineering	Miss J Williams ext 2110
Materials	Dr S Milsom ext 2338
Environment	Mr N L Williams ext 2353
Process engineering	Mr S D Ward ext 2101
Particulate technology	Dr R K Burdett ext 2476
Fluid mechanics and thermodynamics	Mr J Farrow ext 2117
Applied mechanics, electrical engineering	Mr C P Whitlock ext 2350
Joint ESRC-SERC, studentships & fellowships	Mr G Richards ext 2300
Information dissemination	Mrs J Broughton ext 2238
Design	Mr A Spurway ext 2102

DIRECTORATES

ACME (including manufacturing processes)	Ms H Lennon ext 2106
Marine Technology	Mr C C Bray 01-930 9162*
Polymer Engineering	Mr P D Rice 01-235 7286*
Teaching Company	Mr G Brooks ext 2335
Biotechnology	Ms J C Orme ext 2310
Information Technology	
Alvey	Dr D Worsnip ext 2104
Control and instrumentation	Mr P Hicks ext 2401
Computing	Mr M Hotchkiss ext 2260
Communications and solid state devices	Miss P C Davis ext 2161
Microelectronics facilities	Dr K D Crosbie ext 2448
Education and training	Mrs P Kielty ext 2428

NUCLEAR PHYSICS DIVISION

Nuclear structure, studentships & fellowships	Miss L C Gosden ext 2331
Particle physics	Dr A E A Rose ext 2278
CERN	Mr J D Walsh ext 2271

SCIENCE DIVISION

Biological sciences and pharmacy	Mr N Birch ext 2125
Computing	Mr D K Majumdar ext 2421
Mathematics	Mr F Hemmings ext 2312
Neutron facilities	Mr D M Schildt ext 2212
Physics	Mr A J Parsons ext 2261
Science-based archaeology	Mr A G Game ext 2361
Laser facility	Physics Secretariat ext 2215
Chemistry and pharmacy	Dr J Wand ext 2263 Dr P Sharma ext 2166
Synchrotron radiation facility	Dr E J Wharton ext 2222
Cooperative Grants (Science)	Mr J Baker ext 2412

FINANCE

Account queries	Mr S Pridding ext 2434

RESEARCH GRANTS

Most enquiries should be addressed to the appropriate subject committee.

Terms and conditions/ supply of forms	ext 2405

STUDENTSHIPS: APPLICATIONS

Advanced course studentships	ext 2414
Research studentships	ext 2316
CASE	ext 2138
Studentships tenable abroad and general enquiries	ext 2137

STUDENTSHIPS: CURRENT

Ask switchboard for current studentships for your institution

FELLOWSHIPS

Postdoctoral (home, overseas and NATO), advanced and senior fellowships	ext 2172
Special Replacement Scheme	ext 2352
Industrial Visiting	01-222 2688†
Royal Society/SERC Industrial	ext 2206
AAT	ext 2417
CERN	ext 2325
ESA	ext 2219

Visiting fellowships on grants: Enquiries should be made to the appropriate subject committee.

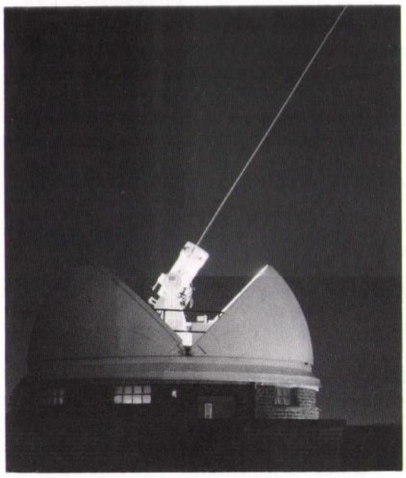
INTERNATIONAL COLLABORATION (except NATO and SERC studentships and fellowships tenable overseas)	exts 2121, 2404 or 2253
SERC BULLETIN	ext 2120

* For London addresses, see inside front cover.

† All enquiries about Industrial Visiting Fellowships should be made to: Fellowship of Engineering, 2 Little Smith Street, London SW1P 3DL.

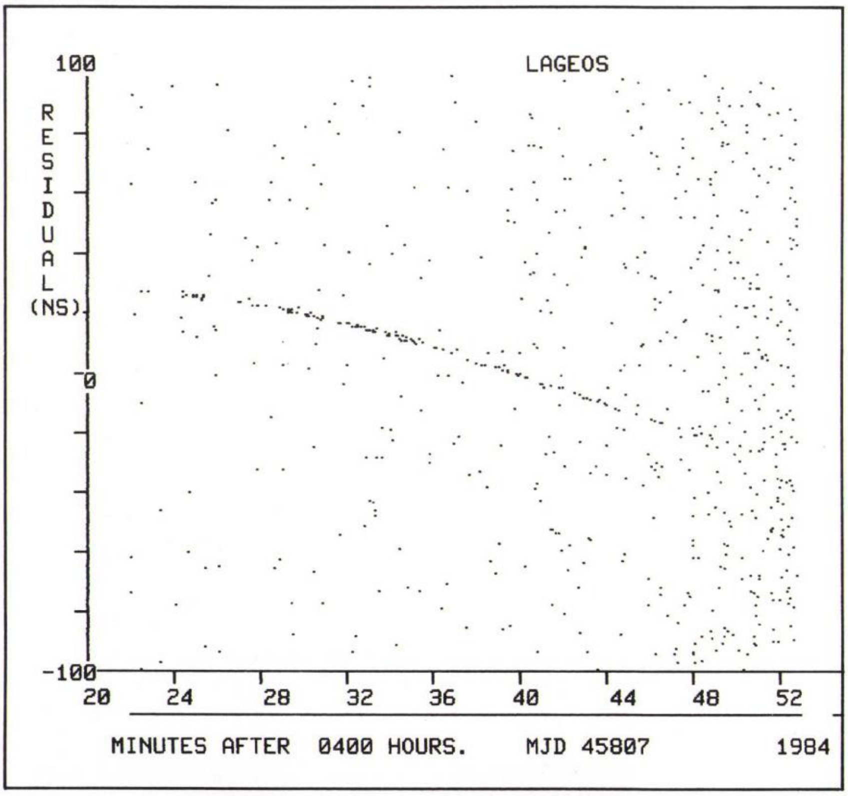
Satellite laser ranging at Herstmonceux

Laser ranging is the most accurate technique available for observing the orbits of artificial satellites. Although it can be used only with satellites carrying retroreflectors, these are entirely passive, long-lasting, light and small, and so are relatively easy to fit to satellites whose precise positions need to be known.



The satellite laser ranging system at the Royal Greenwich Observatory (RGO) obtained its first returns from the satellite Lageos in March 1983. More observations were made throughout the spring and summer while commissioning continued. It has been in regular operation since October 1983 and is now recognized as one of the most effective installations of its kind in the world.

The technique uses time-of-flight measurements with short pulses of light to determine the range to a satellite as it moves in orbit around the Earth. The equipment at RGO can work both by day and night, provided that the skies are clear. Its single-shot precision of better than 5 cm is typical of the ten or so 'third-generation' systems that are now participating in a world-wide campaign of coordinated observations. A single satellite pass, lasting up to 40 minutes, may yield more than 1000 returns; for each return, only one photon is detected. Ranging accuracy is ultimately limited by the correction for the slower speed of light through the atmosphere. The correction amounts to about 2 m at the zenith and is computed from meteorological data; the estimated uncertainty of the model is about 2 cm. Zero-point calibration is by ranging to local targets, and the observations are dated to within 1μs so that they may be properly combined in analyses with others obtained elsewhere. The only other correction needed to obtain absolute ranges for orbit analysis is the displacement between the centre of mass of the satellite and the effective reflecting surface; for spherical or stabilised satellites this is easily determined. There is no significant scale error, because the time-of-flight technique is invoked in the recently adopted definition of the metre, and the SI second is accessible through the clocks of the Greenwich time service with a long-term accuracy approaching 1 part in 10^{13}.



A real-time plot of the residuals from the predicted time-of-flight to Lageos. The noise background is from the dawn sky. A residual of 100 ns corresponds to a range error of 15 m. At each end of the trace the range is 10,000 km; closest approach, in the middle, is 6000 km.

The equipment at RGO was built jointly by the RGO and Hull University, and its procurement was funded by SERC. There is, however, recognition that its observations are potentially valuable outside the normal fields of responsibility of SERC, and both the Department of Trade and Industry and the Ministry of Defence have recently agreed to contribute funds to support a minimal level of observing activity over the next three years. It is hoped that the Natural Environment Research Council may also increase their contribution towards operating costs in future, since several potential applications are within its field.

At present operations are scheduled to cover three passes per day of Lageos (the laser geodynamic satellite launched by NASA in 1976) with ranging to Starlette (a similar but smaller French satellite in a lower orbit) being attempted as well whenever its passes occur within the same duty. Both satellites are dense reflector-covered spheres dedicated to laser ranging; Lageos, at a height of 6000 km, is observed primarily to obtain information about the rotation of the Earth and the geometry and deformation of its surface, while observations of Starlette are of greater significance for studies of the Earth's gravitational field, which is more irregular at lower altitude, and of indirect tidal effects.

We expect that in future the system will continue to be used regularly for ranging to Lageos, since it has taken over from the photographic zenith telescope as the instrument operated by the Time Department to provide the UK's contribution to the international services for monitoring Earth rotation. Observations of Lageos are of particular interest at present because they contribute to the MERIT and COTES projects, which are sponsored by the international unions for astronomy, geodesy and geophysics, and which are intended to provide data for use in determining the form of the services for Earth rotation and coordinate systems in the future. The projects called for the simultaneous monitoring of Earth rotation by all available techniques throughout the 14 months up to October 1984, and for the use of these and other observations to establish a unified terrestrial coordinate system that will be suitable for describing the observed rotation and deformation of the real, non-rigid Earth. The projects are providing a data set of a quality that is unlikely to be duplicated during the present century: it will afford valuable opportunities for further investigations of, for example, the recently demonstrated detailed correlation between variations of the speed and axis of the Earth's rotation and the angular momentum of the atmosphere as deduced from global meteorological data.

Observations of Lageos from Herstmonceux are also likely to be significant for other projects now being planned, such as WEGENER which aims to study crustal deformation in the Eastern Mediterranean by using mobile laser ranging stations funded by West Germany, Holland and the USA. The geologically stable site at RGO should provide a valuable anchor for the network, and the observations will contribute to the accurate determination of the orbit of Lageos. It is hoped that eventually the UK will have its own mobile Satellite Laser Ranging (SLR) system for use in projects of this kind.

Other satellites that are likely to be observed are those carrying radar altimeters: ERS-1 (planned by ESA) and TOPEX (by NASA) are both expected to be in orbit around the end of the decade. Data from such satellites will make it feasible to study the spatial and temporal variations of the height of the surface of the sea, or of the snow and ice in polar regions, and hence to obtain information about ocean currents and eddies, and the profile and structure of the ocean floor; but the proper interpretation of such data requires precise knowledge of the orbit, which can only be obtained by fitting accurate observations to a detailed model of the forces acting on the satellite. Although Lageos and Starlette are dense spherical satellites whose orbits are relatively insensitive to imperfectly modelled non-gravitational perturbations, this is not true of active satellites for altimetry; preliminary work with other satellites at comparable heights will therefore be desirable to ensure that accurate orbits will be available when they are needed.

Herstmonceux is well placed for observing the satellites as they survey the North Atlantic and the North Sea.

The SLR telescope also has the potential to perform directional tracking of sunlit satellites at night, regardless of whether they carry retroreflectors. This would have the advantage over photographic methods that the results would be available immediately. The telescope drive sytem is regularly calibrated by observing stars and accuracies of a few seconds of arc should be possible. This mode of operation has already been demonstrated, but a small amount of additional equipment and some modifications to the control software would be needed to make it available on a regular basis for a wide range of satellites; it could be used between ranging passes, and would increase still further the value of the telescope for the study of the gravity field of the Earth and the properties of the upper atmosphere.

The priorities for observing are set by management and advisory committees which contain representatives of the universities and of government departments and research council establishments. Observing is the responsibility of RGO but our role is not simply to provide SLR observations for others to use, although this is an exacting task in its own right. Integration of telescope, laser and receiver with software for satellite prediction, instrument control, data capture and initial filtering, to produce a reliable system that can be operated by one person, has taken considerable skill and effort. The process of observing is still onerous and is made even more so by variable weather and the need to ensure that laser operations present no hazard to the occupants of aircraft. Raw observations of high accuracy are now being obtained with a regularity that has been matched by few other stations and, as a result, research workers at the RGO and elsewhere in the UK have access both to our own data and to those collected by NASA from other sites. These data are far more accurate than have been available in the UK before, and more sophisticated software packages must be developed to extract significant results from them.

A start on this has been made at RGO, where programs have been developed to compute precise orbits and fit them to the observations. For Lageos, a 30-day arc with data from 10 stations has been fitted with rms residuals of 22 cm, while for Starlette a 5-day arc with six stations yielded 50 cm rms. Clearly much more work must be done before the full accuracy of the observations can be exploited. Work on the analysis of SLR data is also being carried out at Aston and Nottingham Universities. Data and software can be made available to other groups and initial enquiries should be addressed to RGO.

Dr John Pilkington
Royal Greenwich Observatory

The main control station of the SLR facility. This is not usually manned during satellite ranging, because the operator must maintain a radar-assisted visual watch for aircraft from the platform surrounding the telescope. Controls and displays requiring urgent attention are duplicated.

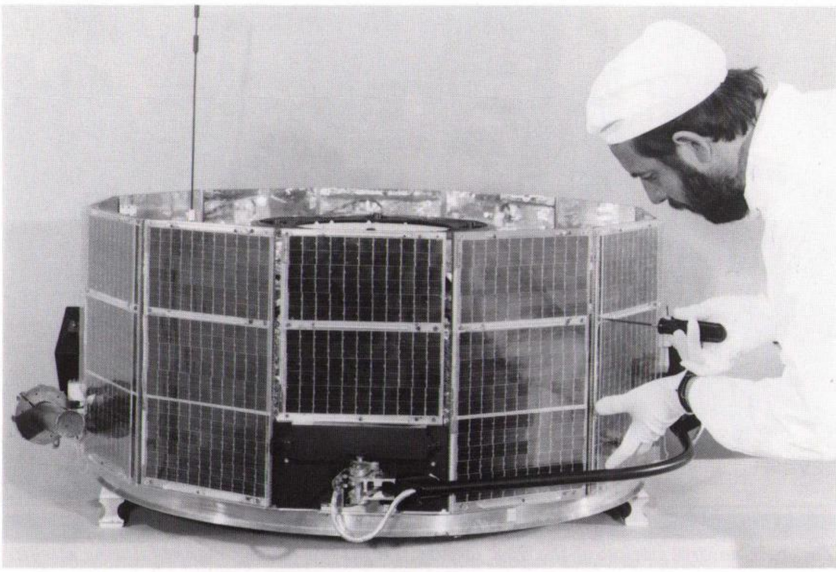
AMPTE—launched and active

The three satellites of the Active Magnetospheric Particle Tracer Explorers mission (AMPTE) were launched successfully by a Delta rocket from the Kennedy Space Center on 16 August 1984. The satellites from West Germany, the USA and the UK have now begun to perform an ambitious series of experiments, some of which involve injections of tracer ions, to discover the mechanisms which govern the entry of particles of the solar wind into the Earth's magnetosphere and atmosphere (see *SERC Bulletins* Vol 2 Nos 4 and 11). The West German spacecraft, the Ion Release Module (IRM), was designed and produced by the Max Planck Institute for Extraterrestrial Physics near Munich; the American Charge Composition Explorer (CCE) by the Johns Hopkins Applied Physics Laboratory near Baltimore; and the United Kingdom Satellite (UKS) jointly by the Rutherford Appleton Laboratory (RAL) and the Mullard Space Science Laboratory who, together with Imperial College, London, and Sheffield and Sussex Universities, produced a comprehensive set of instruments to observe positive-ion and electron distributions, the magnetic field, and electric and magnetic wave activity.

The launch

Although there had been a last-minute delay of one week due to problems with a computer used for orbit calculations, and then because of contamination of the payload by flaking mylar in the air conditioning duct from the launch tower, the launch still took place within a two-week window set three years previously at a time when the UK team entered the project. The launch sequence went exactly to plan. The three spacecraft were injected into an eccentric orbit of 500 km perigee altitude by 9 Earth radii (Re) geocentric distance at apogee. The CCE separated from the others to remain in this orbit within the magnetosphere for the duration of the mission. On 17 August the IRM and UKS were boosted into their mission orbit of 500 km x 18.5 Re which extends outside the magnetosphere and into the solar wind. It was not until 19 August, after a full traversal of this 44 hour orbit, that the UKS separated from the IRM and began a transmission which was received at the UK Operations and Control Centre (UKOCC) at RAL at Chilton in Oxfordshire. By the end of the 10 hour period for which the UKS was 'visible' from Chilton, its spin axis has been re-oriented by pulses from its gas jets, its rigid booms had been deployed and the process of checking its many instruments and systems had begun. Since 25 August the UKS has, like its German and American counterparts, been performing a regular series of studies of the natural medium and the disturbances produced by the injections of ions from the IRM.

The UKS is controlled and operated for typically 5 hour periods each day from the UKOCC via the 12 metre antenna at Chilton. Data reception is shared equally between this antenna and the 26 metre antenna at Chilbolton in Hampshire. At the UKOCC the observations made by the instruments on the satellite appear only moments later as line plots and colour spectrograms which provide continuously forming images of the medium through which the satellite is moving. This permits optimisation of the highly versatile instruments and enables assessments to be made of conditions currently prevailing in the solar wind and magnetosphere.



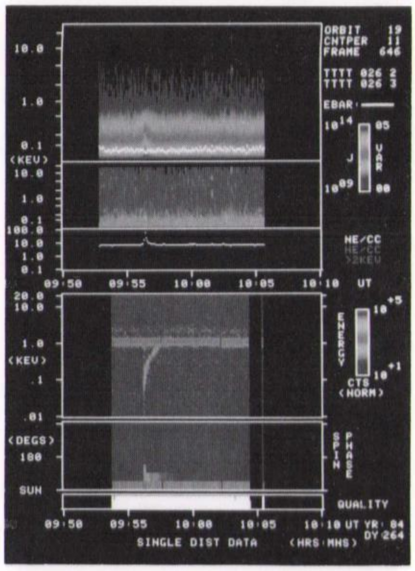
The AMPTE-UKS Satellite being prepared for shipment to the Kennedy Space Center.

Lithium ion releases

Two of the main aims of the AMPTE mission are to trace the flow of solar wind ions into the Earth's magnetosphere using lithium ions injected upstream in the solar wind and to evaluate the effect caused locally by the introduction of these ions.

The first such experiment was performed on 11 September when the three spacecraft were suitably positioned in their orbits and the solar wind conditions as evaluated by the IRM and UKS were thought to be conducive for the entry of solar wind particles into the magnetosphere (principally the magnetic field in the solar wind being directed southward to oppose and cancel the northward field in the outer magnetosphere). Two of the IRM's sixteen canisters were ejected and when they were 1 km from the IRM a lithium-copper oxide reaction was activated to release an expanding cloud of lithium atoms which became photoionized by solar ultraviolet radiation. The effects were immediately apparent at the IRM and the UKS, 35 km away at the time. As expected the expanding plasma of ions and electrons produced a cavity in the solar wind magnetic field with a correspondingly enhanced field outside. The lithium ions were accelerated by the ambient electric field, and solar wind electrons were energized as a result of the disturbance. An intensive search began at once among the rich variety of magnetospheric ions being identified by the CCE for the arrival of some of the lithium ions. So far none have been discovered and the important implications of a possibly negative result are carefully being considered. For this first lithium release the IRM and UKS were both out of sight of their respective ground stations and their data were received and recorded by NASA's Deep Space Network station in Canberra.

A second lithium release was made on 20 September, this time with the UKS visible from Chilton where the antenna was used for commands, and Chilbolton where data were received. The figure (right) taken from the real-time display at the UKOCC shows how the lithium ions were accelerated and solar wind electrons energized during this second release.



Electrons and positive ions recorded by the AMPTE-UKS at the time of the lithium-ion release on 20 September 1984. The six panels taken from the real-time display show the development of (from the top) electron intensity, according to the colour scale at the right, as a function of energy; the degree of directionality of the electrons as a function of energy; electron density; colour-coded count rate of the positive-ion detector as a function of energy; the azimuthal distribution of ions in the ecliptic plane; and a measure of the quality of the positive-ion data.

Clearly seen (in panel 4) are the curved trace formed by the accelerating lithium ions, and the horizontal traces formed by solar wind protons of 1 keV and alpha particles of twice the apparent energy. Electron heating caused by the release is indicated by a temporary increase in electron intensity (top panel) and a corresponding density enhancement (panel 3).

The science teams from all three spacecraft met at the Johns Hopkins University in October to begin a coordinated assessment of the results of these first two of the mission's seven active experiments.

Artificial comet and other releases

As a result of the Earth's annual motion around the sun, by late December 1984 the IRM and UKS no longer penetrate the upstream solar wind but are ideally positioned for a release of barium ions on the dawn flank of the magnetosphere where they are to produce an artificial comet. The progression of the orbits is such that this event, with the IRM in the head of the 'comet' and the UKS in the tail, should take place on Christmas Day.

Further releases in March and April 1985 in the downstream tail of the magnetosphere will, in addition to being further sources of tracer ions, enable studies to be made of perturbations caused in the relatively stationary plasma which prevails in this region. One of these releases is expected to produce an artificial aurora.

Natural studies

Meanwhile, the three spacecraft are continuing to explore the natural magnetosphere and solar wind with a resolution, afforded by their advanced instrumentation, that has not previously been possible. The phenomena of special interest to date have been the structure and composition of the solar wind, the energization of particles as they cross the bow shock formed upstream from the Earth and the equally intriguing process of the merging of solar-wind and magnetospheric plasmas and fields. The mission, which is currently scheduled for a period of 15 months, is after only the first four of these clearly well on the way towards fulfilling its promise of pioneering a new era in space plasma physics.

Dr Duncan Bryant
RAL

Some new publications from SERC

Council's annual report

The Report of the Council for the year 1983-84 has been published. Copies are available from HM Stationery Office bookshops price £5.00 (ISSN 0261-7005; ISBN 0 901660 63 9).

SERC handbooks

New editions of all three SERC handbooks are now available. Copies of *SERC Fellowships 1984-85* may be obtained from SERC Central Office, Swindon, ext 2172; *SERC Research Grants 1984* and *SERC Studentships 1984-85* from the Registrar (or equivalent administrative officer) in each university or polytechnic, or from SERC Central Office, Swindon, ext 2405 *(Research Grants)* and ext 2137 *(Studentships)*.

Marine technology courses

Copies of the 1984-85 brochure, *Short courses in marine technology*, are available from the Marine Technology Directorate, Garrick House, 3-5 Charing Cross Road, London WC2H 0HW; telephone 01-930 9162.

Nuclear Structure

Copies of the *Nuclear Structure Committee Annual Review 1983-84* are available from the Committee's Secretariat at SERC Central Office, Swindon (ext 2223).

Particle physics

Copies of the *Particle Physics Committee Annual Report 1983-84* are available from the Committee Secretariat at SERC Central Office, Swindon (ext 2325).

Energy in buildings

The Environment Committee has produced *Energy in Buildings Specially Promoted Programme: report for the years 1979 to 1984*. Copies of the report are available from SERC Central Office, Swindon (ext 2165).

Building utilisation

The transactions of a seminar sponsored by SERC's Building Subcommittee, the British Council and the Design Research Society have been published. Copies of *Design for building utilisation*, edited by J A Powell, I Cooper and S Lera, are available from Professor J A Powell, School of Architecture, Portsmouth Polytechnic, King Henry Building, King Henry I Street, Portsmouth PO1 2DY, price £25.

Machines and power

Copies of the *Machines and Power Committee annual report 1983-84* are available from the Committee Secretariat at SERC Central Office Swindon, ext 2200.

Biological sciences

Copies of the *Biological Sciences Committee annual report 1983-84* are available from the Committee Secretariat at SERC Central Office, Swindon ext 2264.

Physics

The Physics Committee Annual Review 1983-84, including statistical information, is available from the Committee Secretariat, SERC Central Office, Swindon, ext 2215.

Hawaii's new telescope progress

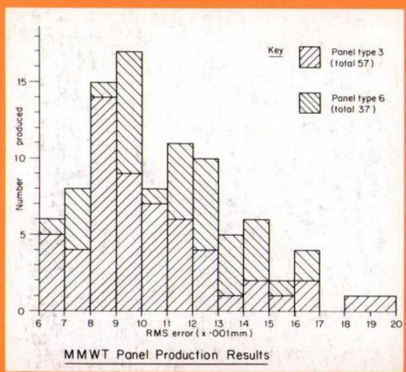
The UK/NL Millimetre-wave Telescope Project is still on course for construction to be complete in the first half of 1986. In 1984 significant progress was made both in Hawaii where the enclosure is being built and in Europe where the antenna is being pre-fabricated before shipping to Hawaii. All major contracts have been placed, except for some elements of the initial set of receivers which have been affected by restrictions on the rate of spend.

Despite an extended and eventful sea voyage, the components of the enclosure arrrived in Hawaii in May 1984. Starting the erection some seven weeks late, the main contractors, Robert Watson and Co Ltd of Bolton, and their Hawaiian sub-contractors, Mutual Welding Co of Honolulu, erected the enclosure to weathertight conditions by October, virtually on schedule. Commissioning began shortly afterwards.

Meanwhile back in Europe progress on the antenna itself has been equally good. Production of the surface panels began at Rutherford Appleton Laboratory (RAL) early in 1984 and by the autumn more than a third of the 276 panels had been made. Although the mechanical specification for the surface accuracy of the panels is approximately 25 microns rms, almost all of the panels produced have been within the goal of 15 microns rms. This improvement in accuracy should allow the usefulness of the telescope to be extended well into the sub-millimetre part of the spectrum.

The contract for the antenna structures was placed with Genius Fabricage BV of Ijmuiden in the Netherlands in March 1984. By September not only were the components for the main frame and sub-frame well advanced but the building needed for the trial assembly and testing of the structures had been erected. Also, the first six of the 12 sectors which will form the backing structure had been fabricated and found to be well within specification by RAL inspection staff.

The UK/NL Telescope enclosure during fabrication on site at Mauna Kea, Hawaii, September 1984



Histogram of the accuracy of the surface panels up to September 1984 (microns)

Most of the ten receiver research and development workpackages begun in 1983 are either complete or nearing completion. Taking this into account, the Receiver Working Group has established a programme for the construction of receivers, first for the commissioning of the antenna and then for the completion of the initial set of receivers. The commissioning receivers are comprised of a continuum receiver covering the wavelength range from 200 to 800 GHz and a line receiver operating at 230 GHz (1.3 mm). The continuum receiver will be produced by the Royal Observatory, Edinburgh, based on work done at Queen Mary College, London and the line receiver will be the joint responsibility of the Mullard Radio Astronomy Observatory (MRAO) at Cambridge and RAL. Intermediate frequency equipment will be the responsibility of the National Foundation for Radio Astronomy (NFRA), Dwingeloo in the Netherlands, and the correlators the responsibility of Kent University.

The remaining receivers planned for the initial provision are line receivers operating at 345 GHz and 470 Ghz, the former to be provided by NFRA and the latter by Queen Mary College in conjunction with MRAO and RAL.

In parallel with the receiver construction programme, a modest development programme will continue to allow the performance of the system to be enhanced and improved with particular emphasis on extending the frequency range.

In order to maintain progress and fulfil the programme requirements, the first members of the RAL installation and commissioning team are planning to take up residence in Hawaii before the middle of 1985. They will be joined by the main body of the team when the antenna structures are delivered to the island this summer. Although we may not see the dramatic progress witnessed last year during the erection of the enclosure, we nevertheless expect to see equally important changes to the inside of the building during 1985.

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