SERC bulletin

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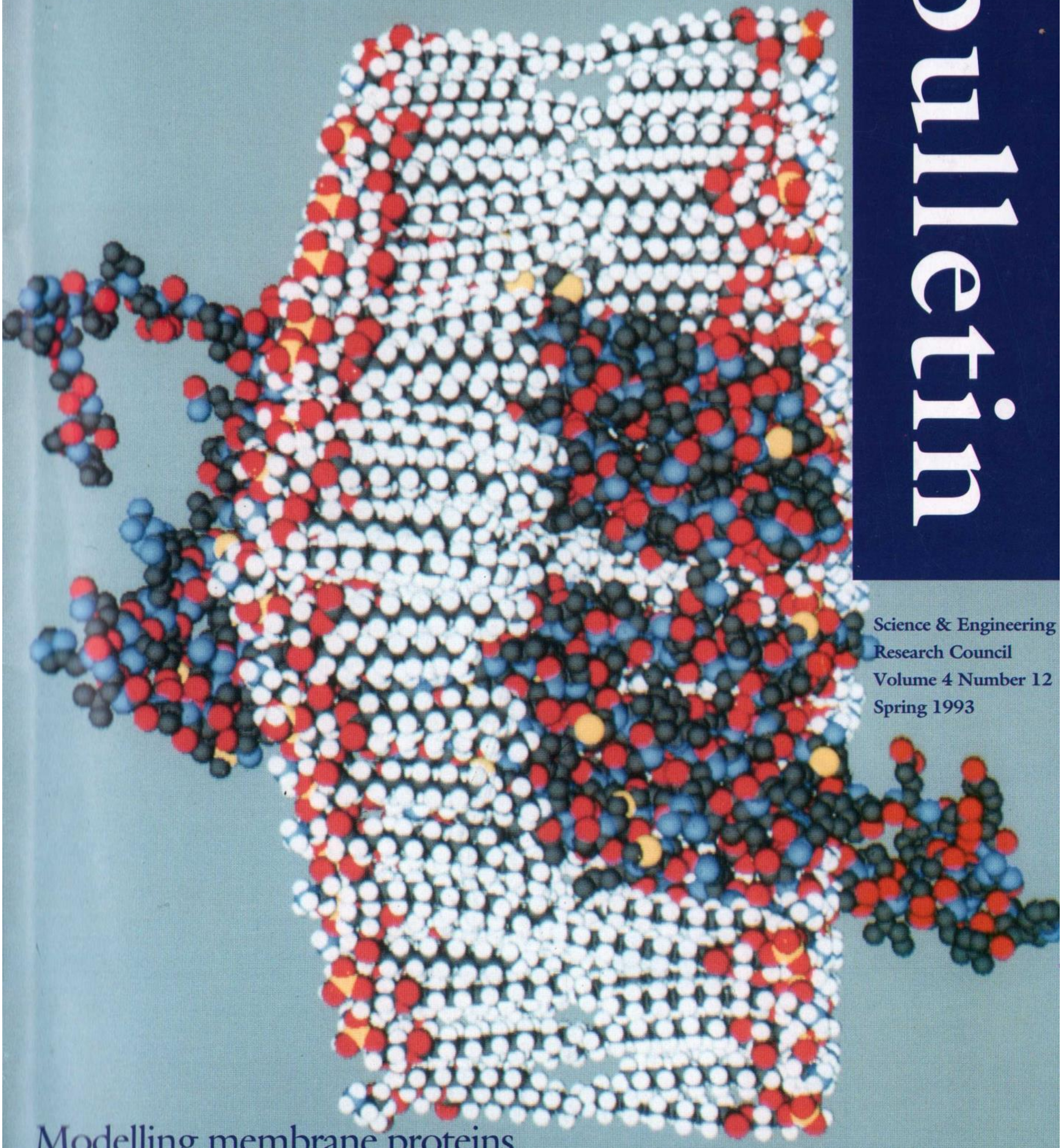
Spring 1993



Modelling membrane proteins

Biotechnology ten years on

Optical fibre amplifiers

SERC's submission to the "White Paper"

SERC

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

Establishments of the Science and Engineering Research Council

SERC Swindon Office
Polaris House, North Star Avenue
Swindon SN2 1ET
Telephone Swindon (0793) 411000
(or 41 + extension number).

SERC London Office
22 Henrietta Street,
London WC2E 8NA
Telephone 071-836 6676

Rutherford Appleton Laboratory (RAL)
Chilton, Didcot, Oxon OX11 0QX
Telephone Abingdon (0235) 821900

Daresbury Laboratory
Daresbury, Warrington
Cheshire WA4 4AD
Telephone Warrington (0925) 603000

Royal Greenwich Observatory (RGO)
Madingley Road,
Cambridge CB3 0EZ
Telephone Cambridge (0223) 374000

Royal Observatory, Edinburgh (ROE)
Blackford Hill, Edinburgh EH9 3HJ
Telephone 031-668 8100

UK Research and Higher Education European Office
Rue de la Loi 83, BP10
B-1040 Brussels, Belgium
Telephone 010-322-230-5275
Fax 010-322-230-4803
E-mail: UKEO@UK.AC.RL.IB

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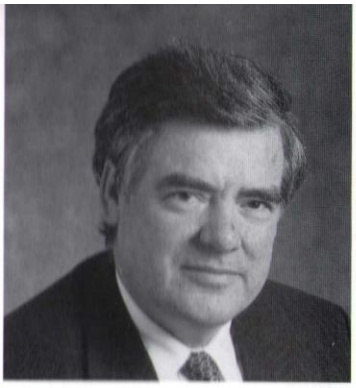
New Council Members

Two new members of the Science and Engineering Research Council have been appointed by the Secretary of State for Science. They are Professor Raymond Smallman CBE FEng FRS, Vice Principal of Birmingham University, and Dr Geoffrey Robinson, Chief Adviser on Science and Technology at the Department of Trade and Industry.

Professor Ray Smallman CBE

Professor Smallman has been Vice Principal at Birmingham for the past five years and is also Vice President of the Federated European Materials Societies.

After the award of his PhD in 1953 he worked at the Atomic Energy Research Establishment, Harwell. At Birmingham University, he has been Professor of Metallurgy and Materials Science, Dean of the Faculty of Science and Dean of Engineering.



Dr Geoffrey Robinson

Internationally, Professor Smallman has held visiting appointments at several overseas universities and is an Honorary Professor at the University of Hong Kong. He has carried out research into the relationship between microstructure and properties in a wide range of metals and alloys, principally using electron microscopy. He is now working on the deformation and structure of nickel and titanium-based intermetallic compounds, ductile cast-irons and textured materials.

Dr Robinson studied mathematics at Nottingham University and carried out research work in quantum physics and chemistry for his PhD.

He joined IBM in 1969 and has been Design and Development Manager for advanced products in software, Technical Programmes Adviser, and Technical Director.

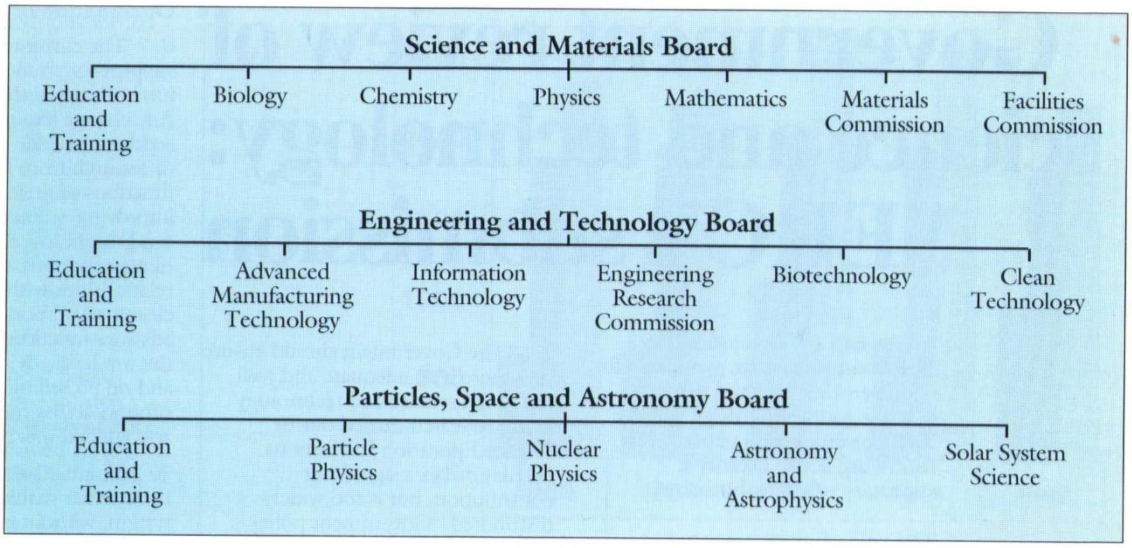
Dr Robinson was appointed Director of Hursley Laboratories in 1988. His role at the DTI is advising the President of the Board of Trade and ministers on scientific and technological issues.

He oversees strategic scientific issues accross the whole range of DTI's activities and represents it in the most senior inter-departmental and scientific forums.

IN THIS ISSUE

Front cover picture

Modelling membrane proteins. CPK-type representation of a model of a lipid bilayer with partial cut-away showing the model of the glucose transporter embedded in the membrane. **See page 12.**



New Board structure for SERC

SERC is to have a new Board structure, consisting of three Boards, which will come into being in the autumn of 1993. The Council finalised plans for the new structure at its meeting in October 1992. This followed the review announced in the 1991 Corporate Plan and several discussions on the issues at Council and Board meetings in the past year. The discussions covered in particular the management of the interfaces between Boards.

Three Boards

The overall remits of the three new Boards are as follows and committee-level structures are shown in the diagram.

The Science and Materials Board will cover the fundamental non-clinical biological sciences; physical, organic and inorganic chemistry; condensed matter physics, atomic and molecular physics, optical physics and plasma physics; materials science and engineering; mathematics; science-based archaeology. The Board will also be responsible for SERC support of a number of multi-user facilities including Isis, the Institut Laue-Langevin, the Synchrotron Radiation Source, the European Synchrotron Radiation Facility, the Central Laser Facility and the Central Microstructure Facility.

The Engineering and Technology Board will cover biotechnology; process engineering; electrical and mechanical engineering; construction engineering; environmental civil engineering; integrated control system engineering; marine technology; manufacturing production research; systems engineering; systems architecture; communications and distributed systems; advanced devices and device materials; very large-scale integration research. The Board will also support a number of cross-disciplinary activities including design, clean technology and manufacturing engineering, and a range of facilities for the engineering community. The Board's programme in information technology will be run as now in collaboration with the Department of Trade and Industry (DTI) through the Joint Framework for Information Technology. The Advanced Manufacturing Technology Committee, which advises on the work of SERC's Application of Computers in Manufacturing Engineering (ACME) Directorate, will also continue as a joint body with DTI as now.

The Particles, Space and Astronomy Board will cover particle physics; nuclear physics; astronomy; astrophysics; cosmology; relativistic and quantum physics; solar system science; planetary science; Earth observation and atmospheric physics. The Board will also be responsible for SERC support of major facilities including CERN, the European Space Agency, the Anglo-Australian Observatory, the La Palma Telescopes, the Hawaii Telescopes, EISCAT and Starlink. The Board's Solar System Science Committee will cover Earth observation and link to the Earth Observation Programme Board of the British National Space Centre (BNSC). The Board will also retain its links to the BNSC on space science.

Council Panels

At the same time as the new Board structure is introduced, the Panels and Committees that report directly to Council will be revised. The current seven bodies (Council Policy Group, Awards Panel, Education and Training Panel, Interdisciplinary Research Centres Panel, Industrial Affairs Panel, Scientific Computing Advisory Panel, Supercomputing Management Committee) will become five:

- the Council Policy Group;
- a Higher Education Committee concerned with postgraduate training, fellowships and other higher education matters;
- a revised Industrial Affairs Panel that will also have an oversight of relevant interdisciplinary matters;
- the Scientific Computing Advisory Panel;
- the Supercomputing Management Committee.

Dr Tony Hughes
Director Programmes, SERC

Government review of science and technology: SERC's submission

At the end of November 1992, SERC submitted its proposals for consideration by the Office of Science and Technology for the forthcoming white paper. The following is the executive summary of the submission.

The role of government

1. The Science and Engineering Research Council considers that a review of the Government's policy and practice for science and technology is timely. Science and technology play a vital role in underpinning industrial competitiveness and national security, in securing energy and resource independence and in enhancing the quality of life of individuals and in society as a whole. Government must support science and technology for these reasons, as well as to maintain the intellectual knowledge base of the UK.

2. Government support is appropriate not only for basic and strategic research but also for some aspects of applied research. The Government should also focus on creating the conditions in which technology transfer is likely to succeed. A strong science and technology infrastructure, raised awareness in both the science base and industry of each other's needs and potential, and increased levels of direct interactions between the science base and industry are crucial. Simplified funding schemes are essential to promote this interaction.

Government support for international collaboration can further help the UK to access developments in science and technology from other countries as well as to realise economies of scale and cost sharing in large facilities.

3. The Government plays a critical role in providing the highly skilled people who will be needed by UK industry and commerce in the future. Attention needs to be paid to the quality of education and training at all levels.

4. The Government should ensure that there is an adequate and well resourced science and technology base. Research carried out by Higher Education Institutions (HEIs) makes a significant contribution, but is too widely distributed. Government policy should focus on concentrating resources to create centres of excellence of critical mass, and on maximising the potential of the best scientists and engineers by allowing them to dedicate themselves full-time to research.

The Government should continue to support dedicated research institutes and interdisciplinary research centres where strong capabilities exist, but must ensure that these are regularly and stringently reviewed, and that their activities are outwardly focused. Large-scale facilities and sophisticated instrumentation will continue to be needed, but their provision should be open to competitive tender. The potential for industrial research organisations to act as intermediaries between the science and technology base and industry should be examined.

Copies of the *Government review of science and technology: Submission from the Science and Engineering Research Council* are available from the Public Relations Unit, SERC Swindon office, telephone (0793) 411256.

5. A stable and continuing provision for basic research and training in science and technology is essential if a broad-based and high quality infrastructure is to be maintained in the UK. This provision should ideally be established as a fixed proportion of Gross National Product. In addition, there should be enhanced provision for strategic and applied research of identified national importance.

Organisation of support

6. The current organisation of support for science and technology has both strengths and weaknesses. Any change should focus on clearer separation of the control and support of research from the executive functions of government, on improving accountability for all funds spent, on clarifying objectives of organisations and their relationships with each other, on a clearer separation of executive and advisory functions, on strengthening the top level advisory mechanisms, and on providing more continuity of support across the basic, strategic and applied spectrum.

7. There is potential to address these issues within the current system, without having to resort to costly and disruptive organisational upheaval. If a major organisational change is contemplated, the Government should thoroughly examine costs and benefits before making final decisions.

8. There would be merit in considering a new organisational structure based on 'mission' or field of application. Whilst a number of models are possible, one such model is four organisations covering research and training related to:

- industrial need and resource independence;
- the environment and land use;
- improvements in human health;
- maintaining the intellectual knowledge base.

There are significant merits in keeping these activities in separate organisations in order to provide clarity of purpose, identification of activities with clear sets of beneficiaries, and development of appropriate and tailored service delivery systems.

9. Each of the new organisations should be responsible for the full costs of activities it supports, and should cover the whole range of activity across the basic-strategic-applied spectrum. Relevant funding council, research council and government department spend on science and technology should be subsumed within the new organisations.

10. The new organisations should be free to support research and training in any other relevant organisation, whether it be HEIs, existing research council institutes, government research establishments or industry. The new organisations should be required to market test activities inherited from predecessor organisations.

11. The new organisations should be established with non-departmental public body, agency or similar status and should report to the Office of Science and Technology (OST). There should be a clear executive reporting line between the chief executives of the new organisations and the permanent secretary of OST, and a clear separation of this reporting line from any advisory function.

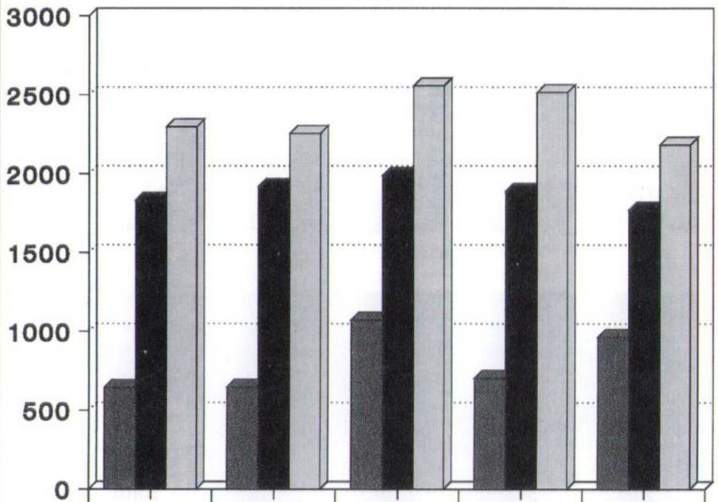
Advisory structures

12. A top level advisory body, reporting to the Prime Minister, should be established to give advice on all government funded R&D, whether pursued with OST funds, or carried out in support of departmental policies. Each department should be free to establish an advisory mechanism appropriate to its specific departmental need. Each new research organisation similarly should ensure that independent, expert advice is sought on its activities at all levels. Peer and/or merit review should continue to be used in project selection.

Improvements to the current system

13. If the current system is retained, there is a need to clarify roles and responsibilities of current funding organisations — particularly Department of Trade and Industry and SERC. A similar clarification of the roles of research councils and OST is needed. This might best be established by implementing framework documents. A revision of the advisory structure, similar to that outlined above, is also needed.

14. Research councils and other funding bodies should be encouraged to apply Next Steps principles and employ market testing to ensure value for money. Financial planning and carry-overs could be enhanced. Government should assume responsibility for costs of inflation and exchange rate changes on international subscriptions, where these changes are different from Treasury planning assumptions.



	1988	1989	1990	1991	1992
CASE	644	647	1073	703	965
RS	1832	1921	1990	1890	1772
ACS	2297	2255	2558	2516	2183
Total	4773	4823	5621	5109	4920

Awarding Year

CASE RS ACS

Postgraduate awards taken up at 1 November, a five year comparison. Note: excludes replacement awards. Source: November Statistics.

Record demand for studentships

Applications for SERC studentships for the 1992-93 academic year reached a record level, with a total 7,753 nominations processed.

Appeals nominations fell slightly to 1,979 compared with last year's total of 2,202. This was as a result of institutions being asked to restrict their appeals nominations to the strongest candidates only.

Standard Research nominations, including appeals, totalled 3,058, compared with 2,912 in 1991. Nominations for Advanced Course studentships were down from 3,814 in 1991 to 3,540 in 1992, mainly due to a fall of 225 in the number of appeals nominations submitted.

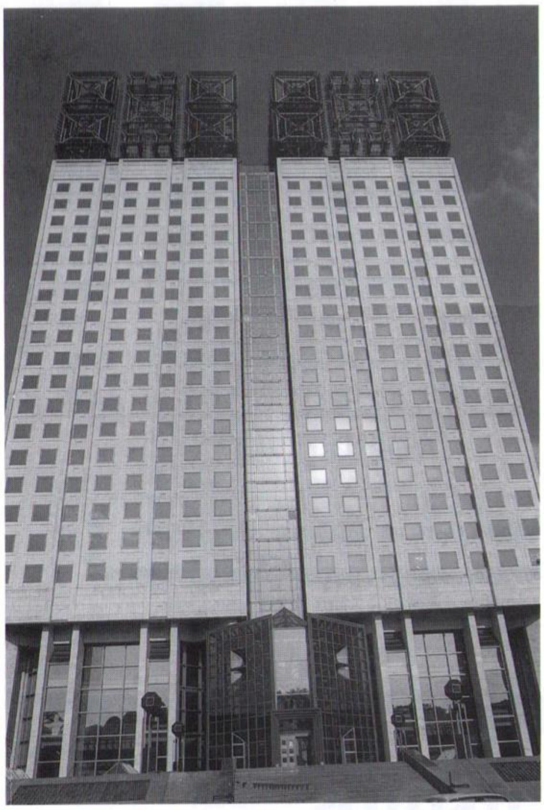
Cooperative Awards in Science and Engineering (CASE) nominations increased to 1,152, compared with 892 in 1991. This increase was principally due to the introduction of a closing date of 31 July for all CASE awards.

The number of awards available for appeals was greatly reduced due to the high level of take-up of quota awards and lack of central funds. Consequently only 169 appeals awards were supported: 77 Standard Research, 49 Advanced Course and 43 CASE.

Awards taken up as at 1 November 1992, excluding overseas, totalled 4,920, compared with 5,109 in November 1991. This total was made up of the following types of award: 1,772 Standard Research, 965 CASE and 2,183 Advanced Course.

A comparison of the take up by 1 November 1992 of different types of postgraduate awards made by SERC in the last five years is shown in the attached graph.

Russian science is down but not out



The new $50-million Academy of Sciences Presidium building. Some leading Academicians have been critical of its cost and design.

With inflation rising at 1% a day, salaries lower than those of a Moscow bus driver and the prospect of mass redundancy at the Academy of Sciences, one might expect to find Russian scientists in gloomy mood. But during a brief visit last September, Secretary to the Council John Merchant found them to be in a surprisingly buoyant frame of mind.

With seemingly undimmed confidence in their ability to carry out world-leading research, the directors of three of Russia's foremost research institutes were still brimming with plans for the future. At the Institute of Radioengineering and Electronics, Yuri Gulyaev, hoping to develop his work on nanotechnology, was about to convert a dusty basement into a clean room equipped for molecular beam epitaxy, lithography and surface analysis. And Boris Vainstein, at the Institute of Crystallography, demonstrated that even with out-dated and home-built equipment, the Institute was still a world leader in various areas of crystallography, and was looking forward to the completion next year of two synchrotron radiation sources in the Moscow area.

But their confidence and enthusiasm could not disguise the general plight of Russian science. Air fares cost several years' salary and there is no hard currency to buy foreign journals, equipment or spare parts. The Academy, traditionally the cradle of Russia's best fundamental science, is in particular trouble. Its budget, despite being doubled between July and September last year, has failed to keep pace with inflation, and as a result the staff of 200,000, dispersed across 351 institutes, may be cut substantially. At the same time, the Academy's influence could be on the wane. The Minister of Science, Boris Saltykov, has set up a research council, modelled on the American National Science Foundation, to award grants for basic research on a competitive basis. Grants will be available to scientists from all sectors and Mr Saltykov is particularly hoping to increase the involvement of universities and ministry institutes in basic research.

During his visit, Mr Merchant met senior figures in the Academy and the Ministry and discussed revisions to the agreements which SERC signed with their Soviet forerunners. He hopes it will be possible for SERC in some small way to help preserve the Russian research effort, but points out that, despite the optimism of Russian scientists, there should be no doubts about the severity of the problems they face.

Dr A LeMasurier
SERC Swindon Office

Golden triangle

SERC Chairman Sir Mark Richmond chose the subject "Universities, industry and the science base: a golden triangle" when he delivered the Irvine Memorial Lecture at the University of St Andrews, in October.

Sir Mark, right, is pictured receiving a commemorative medal from the university's Principal, Professor Struther Arnott, accompanied by Head Janitor Mr Jim Douglas, who carries one of the university maces.

Bright sparks: (left to right): Academician Boris Zhukov, Dr Tony Hughes and Professor A Merzanhov.

UK and Russia discuss combustion

An important meeting between British and Russian combustion experts, sponsored by SERC with the support of the Royal Society was held in Abingdon, Berkshire, in July 1992. It involved 16 leading academics and industrialists from each of the two countries, and aimed to provide an exchange of information in four key areas of combustion, and also to catalyse future collaborative activity between Russia and the UK.

The meeting was planned by an organising committee, chaired by Professor Derek Bradley FRS (Leeds University), consisting of Dr Chris Lawn (Rolls-Royce), Dr Phil Rogers (Imperial College of Science, Technology and Medicine, London) and Hugh Thurbon (SERC). Valuable guidance was also received from Professor Alexander Merzanhov (Russian Academy of Science, Chernogolovka).

Interdisciplinary

The event was mainly funded by SERC's Electro Mechanical Engineering and Process Engineering Committees, with additional contributions from its International Section and Materials Commission, and from the Royal Society, reflecting both the interdisciplinary nature of the subject and the wide range of support for the meeting.

Around the formal meeting, a programme of visits was arranged for the Russian delegation. At Harwell the organisation of the Atomic Energy Authority was explained and the current programme of combustion research described. Delegates toured the Clarendon Laboratory and were given a demonstration of its advanced laser diagnostic facilities. Several of the Russian party were able to visit the Rover Test Facility and tour the varied facilities available to the company. At the Royal Society the delegation discussed collaborative opportunities before touring the Royal Institution and Faraday's laboratory.

Organisation of research

Throughout their visit the Russian party were keen to gather details of the way the effective organisation and application of research is carried out in this country. During the meeting at Abingdon an informative talk was given by Dr Tony Hughes, SERC's Director of Programmes on university funding and the research grants scheme, which provoked much discussion.

For the formal meeting four topics were selected for detailed discussion, as follows:

- Solid flames and materials synthesis
- Power generation and incineration combustors
- Explosions and hazards
- Automotive and gas turbine combustion.

The first of these had been selected because of Russian pre-eminence in high temperature synthesis and solid flames and the discussions involved materials as well as combustion specialists. The second topic involved problems of large combustors with incineration posing some particularly difficult problems with regard to chlorohydrocarbons. Some interesting applications of rocketry were revealed by Academician Zhukov, who for a number of years had headed the Soviet rocket programme. A valuable feature of the discussions on explosions and hazards was the detailed information on the tragic consequences of the liquefied petroleum gas pipeline fracture at Ufa in June 1989. The role of pollution legislation was paramount in the automotive and gas turbine discussions, which also elicited interesting information on Russian military and civil gas turbine developments.

Future collaboration

In these discussions delegates acted as both specialists within their own discipline and generalists within the broader fields of combustion and materials. This achieved valuable cross-national and cross-disciplinary fertilisation and identified future research areas where collaboration would be mutually beneficial.

The meeting and associated programme of visits have proved most valuable in establishing links between the two countries. The British delegates were encouraged by the degree to which the Russians were forthcoming on many aspects of their work which previously were closely guarded, and there was a lot of discussion of future research collaborations, research contracts, and further working visits by Russian researchers to British laboratories. Proposals are currently being prepared for a number of Kapitza awards through the Royal Society, and Visiting Fellowship grant applications to SERC. Especial thanks were due to the interpreter Mrs Anna Minnevitch.

Copies of the detailed scientific report of the meeting are available from John Espley, Electro Mechanical Engineering Committee at SERC Swindon Office.

Professor Derek Bradley FRS
Leeds University

Hugh Thurbon
SERC Swindon Office

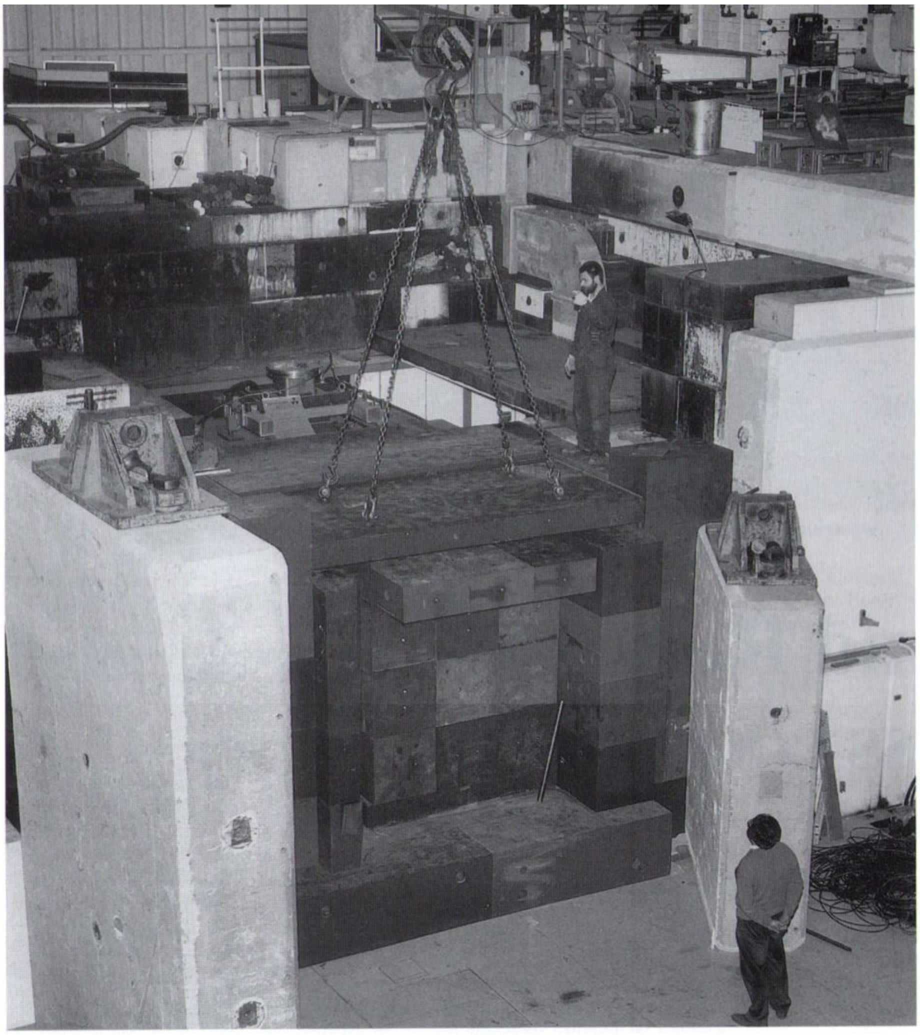


Figure 1: Modifications to the extracted proton beam at Isis showing the steel shielding for the RIKEN pion injection system.

UK-Japan collaboration in muon science

Figure 2: Latest design layout of the RIKEN Muon Facility at Isis.

In March 1989, Pons and Fleischmann astonished the scientific community with their announcement that they had achieved 'cold' nuclear fusion electrochemically. Unfortunately the frantic developments over the ensuing years are now considered to be more of historic rather than scientific interest. Little was discussed about another, but well established form of cold fusion, the negative muon catalysed fusion of the hydrogen isotopes. The electrochemical experiments did however produce at least one important spin-off in that they prompted the Japanese Science and Technology Agency (STA) to make a major investment in muon catalysed fusion research, described here by Dr Gavin Williams of Rutherford Appleton Laboratory.

Professor Ken Nagamine of the Institute of Physical and Chemical Research (RIKEN), Tokyo, had already been the recipient of a modest amount of muon research funding, partly due to the possible implications of muon catalysed fusion for energy production, when in March 1990, at the height of the cold fusion fever, he was able to convince the Science and Technology Agency to award him a major grant of value £7 million to construct a new muon source principally for muon catalysed fusion research. It soon became obvious to Professor Nagamine that the best place to construct the muon source was at SERC's Rutherford Appleton Laboratory (RAL), which contains the world's most powerful pulsed proton source, Isis. Intense beams of pulsed muons are readily produced following pion decays from a thin graphite target placed in the Isis extracted proton beam.

The SERC-RIKEN Agreement in muon science was signed in September 1990 and will last for 10 years. The main elements of the agreement are that the construction of the new Muon Facility is to be funded by RIKEN, that RIKEN and SERC jointly contribute their expertise to its construction, and that the use of the facility is to be shared equally between scientists sponsored by RIKEN and those by SERC.

The Muon Facility comprises three main parts: the graphite pion target and injection system, the extraction beamlines, and the experimental equipment placed at the ends of the beamlines. Project work at RAL up to mid-1991 was concentrated on designing the pion target and injection system. Its construction meant that extensive modifications had to be made to the extracted proton beam at Isis, and this work was arranged in two phases. The main objective of the first phase was to reconstruct the massive steel shielding around the pion target, and this was completed in April 1992 (figure 1). The second phase is the completion of the pion target and injection system which takes place in spring 1993.

The pions collected from the target are injected into a 5.5m long superconducting solenoid (the decay section) which is being built in Japan. The solenoid, together with its complex cryogenic cooling system, will be installed at Isis during the first half of 1993. RAL staff have designed a new helium compressor building and associated services for the cooling system.

Muons are transported from the solenoid to the experimental areas using a system of focusing, bending and kicker magnets – the extraction beamlines. The design of the muon extraction system is now at an advanced stage, and it is anticipated that the first test beam (from the decay solenoid) will be produced in autumn 1993. Figure 2 shows the latest design of the complete Muon Facility.

Experimental facilities will be provided in two experimental areas, and the full scientific programme is expected to begin in July 1994. The RIKEN research programme will largely use negative muons to study the basic physical processes involved in the muon catalysed fusion of deuterium and tritium. The Muon Facility will however also have the capability for providing positive muons over a very wide momentum range (some 30-120 MeV/c) and these can be used as a probe of microscopic magnetism in a variety of materials. The SERC-sponsored programme on the Muon Facility has not yet been formulated; enquiries from potential users will be most welcome and should be addressed to the Muon Group at RAL.

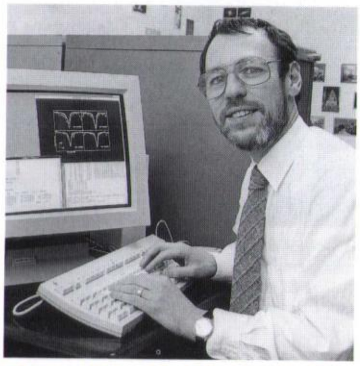
Dr W G Williams
Muon Group
Rutherford Appleton Laboratory
Telephone (0235) 445599.

SERC grant for stellar studies

SERC has awarded a £94,000 grant to a national astronomy project based at the Department of Physics and Astronomy at St Andrews University.

Part of the grant will be used to provide a high-performance computer workstation for the Analysis of Astronomical Spectra Project, which has been based at the university since 1988. The workstation will be used by Dr Simon Jeffery to develop and test complex programs used for simulating the light emitted by stars and galaxies.

The new equipment will also allow astronomers in other countries to have access to programs and data from the project's library of computer software. The astronomers will be able to use the models generated by the programs to interpret information obtained at astronomical observatories worldwide, including the SERC telescopes at La Palma and Hawaii and the SERC-supported telescopes in Australia.



Dr Simon Jeffery of the St Andrews Analysis of Astronomical Spectra Project.

At St Andrews, the programs are used to study the surface of helium stars. These stars are very old and have been turned inside out so that their interiors are exposed, allowing their remarkable structure to be investigated. A recent study by Dr Jeffery and Dr Richard Dudley has shown that one of these stars is likely to become a supernova.

The project is run by a working group of some 15 astronomers from all over Britain, including Dr Richard Carson, the chairman, from St Andrews, and Dr David Flower, from the Physics Department at Durham University.

Power point

Doug Warne has succeeded John Steele as the coordinator for the Electrical and Power Industries (EPI) area of the Electro Mechanical Engineering Committee (EMEC).

He brings to the new position a wide range of experience of the electrical and power industries through his work with GEC-Alsthom, ERA Technology, Electromotors and at present, the Power Electronic Devices and Derived Systems LINK Programme.

Mr Warne's responsiblities will include giving advice on making grant applications in the EPI area of EMEC and helping to coordinate research, particularly in the Electricity Research Cofunded Scheme. All potential applicants in those areas should contact Mr Warne before submitting their applications.

Doug Warne

He can be contacted at:

Piplar's Cottage, Dusthouse Lane, Tardebigge, Bromsgrove, Worcestershire B60 3AD
Telephone/fax (0527) 78267.

A view of the HERA tunnel in which electrons and protons are accelerated to very nearly the velocity of light. The four-mile tunnel runs under the outskirts of Hamburg in Germany. The protons and electrons each travel in their own evacuated pipe, and are guided round by magnets. The large cylinders are the cold superconducting magnets which guide the protons and underneath are the smaller "warm" magnets which guide the electrons.

New era for particle physics experiments

British physicists and their colleagues from all over the world celebrated the start of a new era of particle physics experiments with the inauguration of a new high-energy particle collider in October. Called HERA (Hoch Energie Ring Anlage), it has been built at the Deutsches Electronen Synchrotron laboratory (DESY) in Hamburg, Germany. At HERA physicists can study the head-on collisions of electrons and protons, the basic constituents of matter, at hitherto unavailable energies, writes Dr John Dainton, a SERC Senior Fellow based at DESY.

HERA can be thought of as a giant microscope with which physicists can probe the deep structure of matter. The extremely violent collisions may for the first time reveal a new sub-structure either in protons or in electrons or in both. With the accelerators available during the last 20 years physicists have established that the proton may be understood as a composite of point-like particles, called quarks and gluons, and that the electron itself is similarly point-like. The immensely enhanced resolution of HERA is capable of probing with up to 100 times greater precision these fundamental building blocks of matter, thereby revealing any new and possibly common sub-structure. This will provide a deeper and simpler understanding of the laws of physics and of the origin and present evolution of the Universe.

The electrons and protons are accelerated in a complex of accelerators before they are stored and brought into collision using two rings in a 6-km circumference tunnel under the streets of Bahrenfeld, a suburb of Hamburg.

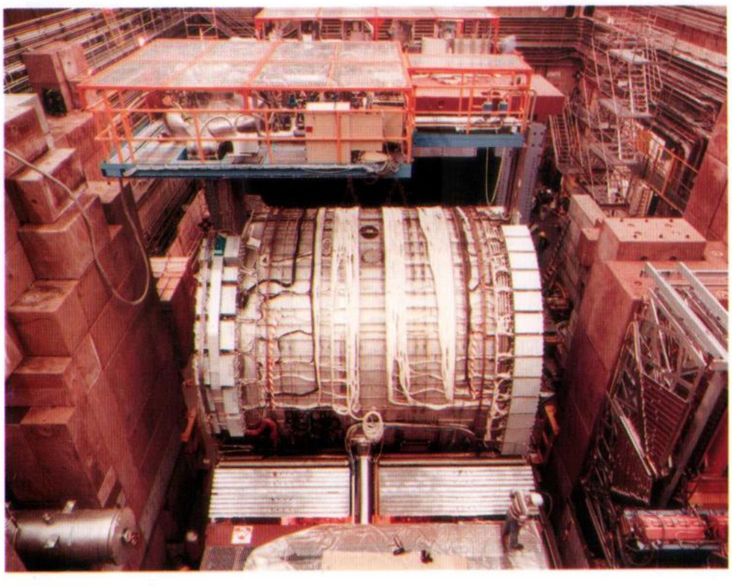
Energy-saving technology

The protons are stored in a stable orbit at an energy of 820 GeV using more than a thousand superconducting electromagnets manufactured by European industry. Each electromagnet operates at a temperature of 4.2 K (-269°C). They are cooled by liquid helium which circulates constantly through the interior of each. The cryogenic system supplying the electromagnets with liquid helium is the largest outside the USA, and is the first use of energy-saving superconducting technology in Europe on a scale usable for future industrial applications.

The electrons are stored in stable orbits at 30 GeV energy in a ring in which it will also be possible to achieve a high degree of 'spin polarisation' for further unique experimental tests.

Experiments are under way using two large detectors, called H1 and Zeus, operated by two international teams of physicists. They have been constructed at two of the interaction points of the colliding electron and proton beams. The detectors, each weighing thousands of tonnes, have taken several years to assemble, using component parts designed and built in Europe, the USA and Russia.

UK groups have been concerned in both H1 and Zeus with components at the heart of each detector. Physicists and engineers from universities and SERC's Rutherford Appleton Laboratory (RAL) have during the past six years designed and constructed sophisticated charged track detectors which will permit the reconstruction of the trajectories of tracks from the violent electron-proton collisions with an accuracy roughly equal to the diameter of a human hair. The Forward Track Detector in H1 is the responsibility of Glasgow, Lancaster, Liverpool and Manchester Universities and RAL. The Central Track Detector in Zeus is the responsibility of Bristol, Glasgow and Oxford Universities, Imperial College of Science, Technology and



The magnetic coil, built at RAL, is lowered into the H1 experiment. When powered, the energy stored in the magnetic field is comparable to the kinetic energy of a passenger train travelling at 100mph.

UK institutes working on physics at HERA

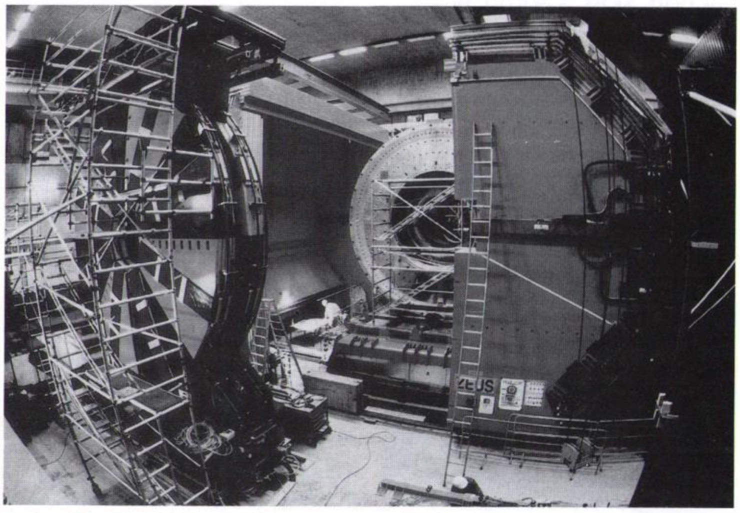
Institute	Experiment	Contact
Birmingham University	H1	Professor John Dowell
Bristol University	Zeus	Dr Brian Foster
Glasgow University	H1, Zeus	Professor David Saxon
Imperial College, London	Zeus	Dr Donald Miller
Lancaster University	H1	Dr David Newton
Liverpool University	H1	Professor Erwin Gabathuler
Manchester University	H1	Professor Robin Marshall
Oxford University	Zeus	Professor Roger Cashmore
Queen Mary and Westfield College, London	H1	Dr Graham Thompson
SERC Rutherford Appleton Laboratory	H1	Dr Bill Haynes
SERC Rutherford Appleton Laboratory	Zeus	Dr Norman McCubbin
University College London	Zeus	Professor Fred Bullock

Medicine and University College London, and RAL. In addition Birmingham University and Queen Mary and Westfield College, London, have contributed sophisticated systems to enable the H1 detector to trigger electron-proton interactions of interest.

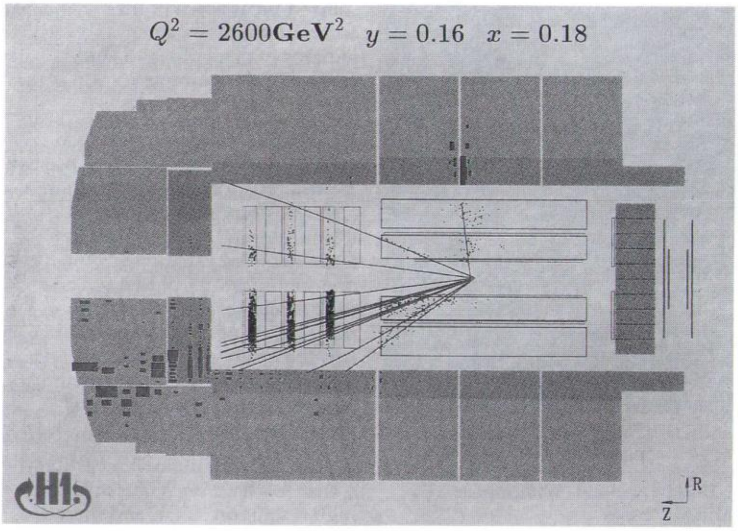
Based on superconducting magnet technology developed at RAL over many years, the large solenoid, in which the H1 charged track detectors operate, was designed and built at RAL.

The inauguration was the climax of eight years' work which started when both the Federal German and the Hamburg city governments approved funding for the construction of HERA in spring 1984. The completion of the HERA accelerator complex involved many international contributions, including the UK's. The successful achievement of first collisions in the summer of 1992 was a milestone for world physics, heralding the start of at least 10 years' exciting new experimental work.

Dr John Dainton
Department of Physics
Liverpool University and DESY, Hamburg



A view of the ZEUS experiment during the installation of the components. The picture was taken before the installation of the tracking detector built by the UK groups in ZEUS. This detector fills the central cylinder seen in the picture.



Computer display of a real electron-proton collision observed in the H1 experiment. Protons from the right collide head-on with electrons from the left. Fragments created in the very energetic collision emerge as secondary particles which are detected in the different component detectors of the experiment. In this particular event, the incident electron is scattered through a substantial angle and is detected as a single charged track. The other fragments appear as a cluster or "jet" from the fragmented proton.

Modelling membrane proteins

All living cells are surrounded by a membrane which acts as a barrier separating the inside of the cell from the environment. This separation is probably one of the most crucial requirements of cellular organisms. Without it the organism could not distinguish itself from the environment or control the chemistry occurring around it.

Recognising the importance of this field, SERC's Science Board set up the Biological Membrane Initiative six years ago to focus funding on the structure and function of membranes and membrane proteins. Dr David Osguthorpe of Bath University describes the work of his Molecular Graphics Unit, supported by the Initiative, on the application of computer simulation techniques in the study of biological molecular systems.

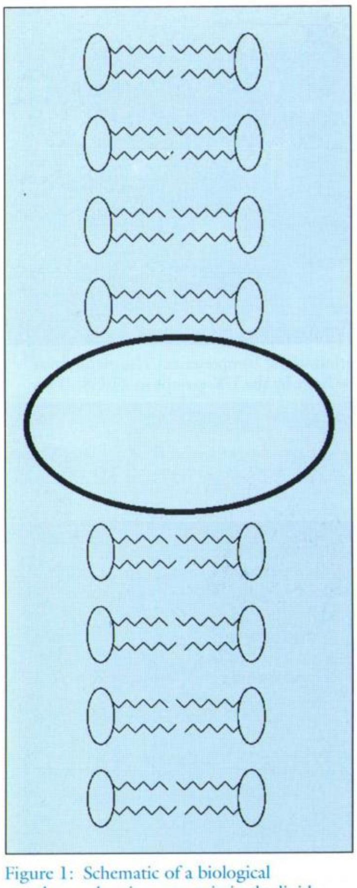


Figure 1: Schematic of a biological membrane showing a protein in the lipids. For each lipid, the ellipse represents the hydrophilic head and the diagonal lines the hydrocarbon tails.

Biological membranes are based on the lipid bilayer, which use the properties of detergents to create a barrier between two different aqueous phases, the environment and the inside of the cell. Having created this impermeable barrier, it must be made selectively permeable, otherwise the cell could not take in raw materials and export waste. This is achieved by the addition of membrane proteins, the transport proteins, which allow molecules to pass through the membrane. For multicellular organisms, additional proteins are found in the membrane which allow cells to communicate with one another. These receptor proteins are crucial to the growth of the organism, the maintenance of different types of cells and protection of the cell from foreign cells.

Medical importance

These molecules are very important in medicine. Most viruses find the cell they can attack by recognising a particular marker molecule on the cell surface. Many drugs act on receptor proteins on the surfaces of cells. A breakdown in the communication between cells is the initiator of many diseases, and control of this communication is the route to many treatments.

Despite their crucial importance, membranes and membrane proteins are still very poorly understood in terms of structure-function relationships. It is now a central tenet of biology that one of the most important features of biomolecules is their three-dimensional structure – the position of their atoms in space. It is this structure which is a prime determinant of their function and how they interact with other molecules.

A problem with membrane proteins is that few have been determined to high resolution so far, and there is a lack of detailed knowledge about the structure of membranes themselves. This is partly because the main technique used to acquire such data, X-ray crystallography, seems to be difficult to apply to membrane proteins. Only two membrane protein structures are known at atomic resolution (less than 2.5Å) with three other medium to low resolution structures from electron microscopy.

Modern biological techniques, in particular molecular biology, have generated a lot of information about membrane proteins. As well as a great deal of amino acid sequence information for membrane proteins, such as transport proteins and receptor proteins, there are also experimental data on their function. Membrane and membrane protein function is so important that we would like to make the best possible use of all these data to determine the structural basis for the function of such systems.

Biomolecular structure

The Molecular Graphics Unit at Bath University concentrates on the application of computer simulation and visualisation techniques to understand the structure and function of large biological molecular systems. Much of the work has been through collaborative projects with groups studying the systems experimentally. This is particularly important when investigating systems for which little structural information is available. The problem of determining the structure of a biomolecule such as a protein from its chemical structure alone is extremely complex and no techniques currently exist for its solution. Hence the need for working closely with experimentalists so that structural models created from the current data can be tested experimentally, for example, by suggesting site specific mutagenesis experiments.

Two membrane protein systems have been studied at Bath up to now: the acetylcholine receptor and the glucose transporter. In both these cases little structural information was available but extensive experimental studies were under way in the Department of Biochemistry. In addition to the modelling work on these two systems, the group is currently performing molecular dynamics simulations of lipid bilayers, as a prelude to full simulations of a protein in a bilayer.

Molecular dynamics simulation is the solution of Newton's equation of

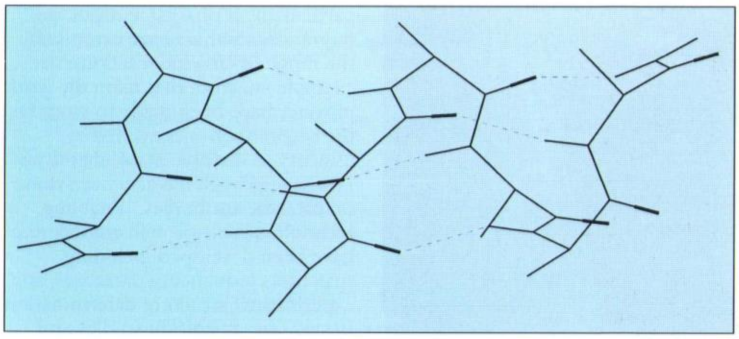


Figure 2: A representation of part of an a-helix with the dotted lines showing hydrogen bonds between the amino-acids. The lines are drawn between the nuclear centre of atoms that are bonded together.

motion for a molecular system. The energies of molecular interactions are computed by an empirical potential energy function. The best of these potentials are given parameters by fitting calculated properties to experimental values for small molecules. Within the classical limit, a molecular dynamics simulation of a biomolecular system using such a potential contains *all* the information necessary to compute any experimentally observable property, including structure, energy, fluctuations and entropy. These simulations are designed to answer one of the major scientific problems in modelling membrane protein systems, the energetics determining the structure of these proteins.

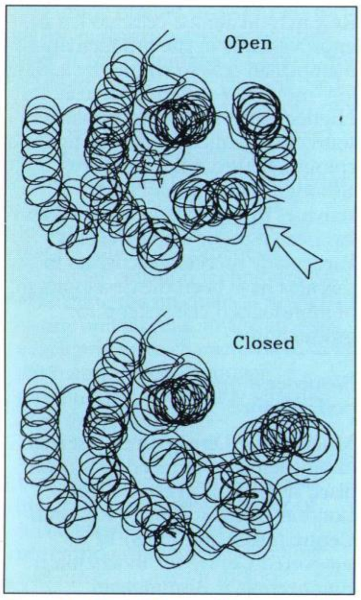


Figure 3: A view of two conformations of the Bath model of the glucose transporter looking down on the membrane surface. The curved lines show the membrane helices of the protein. The arrow in the 'open' conformation of the protein (labelled Open) points to the helix which moves towards the center of the protein to produce the 'closed' conformation, which is shown below it.

The forces controlling membrane protein structure are radically different from those controlling water-soluble proteins, for which we have most structural data. From physical chemistry considerations, proteins in a non-polar medium should favour the alpha helical conformation and it has been generally accepted (without much evidence) that the structure of membrane proteins in the middle of the lipid bilayer is essentially helical (see figure 2).

Glucose transporter

The glucose transporter is fundamental to many cells, transporting the major metabolite glucose across the cell membrane. The red blood cell glucose transporter has been widely studied, at Bath by Dr G Holman of the Department of Biochemistry. No detailed secondary structural information is currently available for this receptor and so a collaborative project was embarked on to create a three-dimensional structural model for this protein. Many amino acid sequences of glucose transporters are known and a multiple sequence alignment was constructed of all sequences available. From this, 12 transmembrane helices were identified which then had to be positioned in space.

This was done on the graphics system by positioning the helices in a way that attempted to satisfy as many constraints as possible, such as the length of linker regions between transmembrane helices, the hydrophobic moments of the helices, and experimental data. This included data on the amino acids that are close to the glucose binding region, data from spectroscopic changes occurring on transport and on specific amino acid mutations that change transport. This led to the construction of the model as shown on the front cover of this *SERC Bulletin*.

A major result from this modelling is a novel hypothesis for the mode of action of glucose transport. A proline-rich region of one of the transmembrane helices creates a flexible hinge at that point, as the proline residue lacks a hydrogen bonding interaction with other residues of the helix. Using this region as a hinge, two sections of the transporter could be moved in relation to each other in such a way as to allow two binding pockets for glucose on either side of the membrane to open and close alternately (see figure 3). This is consistent with much experimental data on the mechanism of glucose transport. Using molecular dynamics, the nature of this flexibility is being further investigated.

Using a range of modelling techniques we have generated a model in atomic-level detail of the glucose transporter which can now provide a basis for further experimental studies on the transporter. In the absence of hard structural data, such as crystallographic structures, modelling is a useful way of encoding the data generated by biochemical experiments into a three-dimensional structural model. This model can be used to devise further experiments which will test it or differentiate between a number of competing models. Understanding of the structure and function of membrane proteins will have a wide range of applications, both to medicine and biotechnology.

Dr D J Osguthorpe
Molecular Graphics Unit
School of Chemistry
Bath University

Detergents (lipids) are molecules which have two properties, a water-liking (hydrophilic) property in a head region and a water-hating property in a hydrocarbon tail region. These molecules can form a surface in which all the hydrophilic head groups are aligned on one face, and the hydrocarbon tails on the other face. Two of these surfaces come together so that the two hydrocarbon surfaces face each other and the hydrophilic faces point to the aqueous environments surrounding the membrane. The two aqueous phases, the external environment and the inside of the cell, are thus separated by a hydrocarbon layer in which the contents of the water phases are insoluble (see figure 1).

A high-speed stream-sterilisable centrifuge on test for biocontainment before installation in the Advanced Centre for Biochemical Engineering, at the UCL IRC.

Biotechnology ten years on

The Biotechnology Directorate (BTD) has recently celebrated its tenth year since it was set up in 1981. Biotechnology covers the application and exploitation of biological organisms, systems or processes in manufacturing and service industries. In recognising the role of other funding bodies, BTD targets the pharmaceutical, chemical and waste processing sectors, focusing on research and training that crosses the boundaries between biology, chemistry and process engineering.

The Directorate has recently redefined its future strategy and programme, and published its *Forward Plan* which sets out its aims for the next five to ten years in the context of market and technological opportunities and areas of UK strength. The *Forward Plan* identifies two main complementary themes, bioprocesses and bioprocessing. Research which integrates these two themes, such as the effect of scale on bioprocesses, is particularly encouraged.

Significant progress has been made during the lifetime of the Directorate and some of the main areas of success are described here by Hugh Thurbon of BTD, divided into the key themes identified in the *Forward Plan*.

Bioactive molecules and biocatalysts

British groups have played leading roles in developing enzymes and other biocatalysts for use in industry, particularly in pharmaceuticals and fragrances. Others have extended the range of enzyme reactions; for example enzymes that naturally work in water have been made to work in the organic solvents needed by industry to dissolve many chemicals. Pioneering work has also been done on catalytic antibodies. Enabling technologies for protein engineering have been developed including structure/sequencing databases, and experimental structure determination from X-ray diffraction studies and nuclear magnetic resonance data. Cell adhesion molecules are now being identified and resolved in molecular detail, work which has many potential applications: for example, the stimulation of cells in bioreactors to make them more productive.

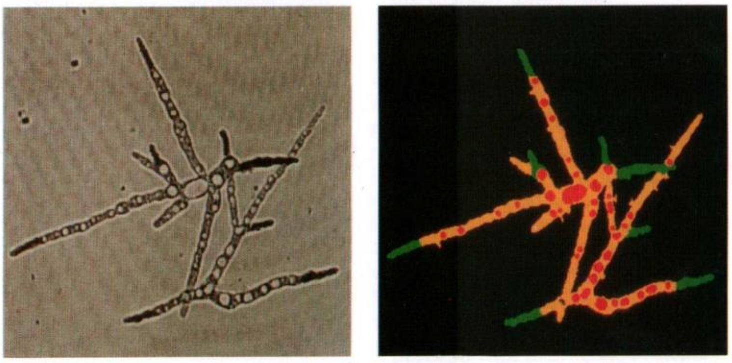
Control and use of metabolism

Research on antibiotic production has led to the development of important fundamental concepts and useful tools in the form of DNA probes, which can be used to study industrial strains. Great progress has also been made in the ability to engineer genetically both microorganisms and higher cells to over-produce specific proteins. However, genetic manipulation can affect the physiology of the host and work is proceeding towards the genetic improvement of host organisms.

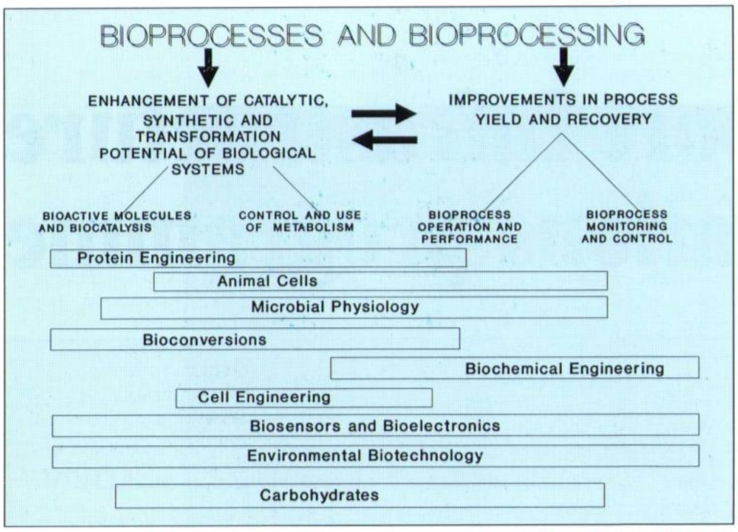
Research on animal cells has led to improvements in the productivity of mammalian cells in culture by adding low-molecular-weight activators. Higher plants have been valuable sources of medicines, flavourings and colourings throughout history, although translation of plant activities from the field to the factory has been fraught with problems. Particularly successful activities in this area have been the development of immobilised cell systems for production.

Bioprocess operation and performance

Much of the Directorate's research in biochemical engineering is taking place at the University College London Interdisciplinary Research Centre (IRC) and the SERC-supported Centre for Biochemical Engineering at Birmingham University. Several years before the concept of IRCs was developed, the Directorate had identified the need to fund centres to the level that would permit scale-up studies, and centres at Birmingham and UCL were launched.



Grey image and corresponding binary image illustrating the use of image analysis to characterise fungal differentiation. From work at Birmingham University Centre.



The relationship of the Directorate's existing programme to the main themes forming the basis for the future programme development.

The UCL programme has developed its theme of total process research by giving particular priority to work on bioprocess simulation and the verification of its predictions at pilot-plant level. In 1989 a link was formed with the IRC in Process Systems Engineering at Imperial College of Science, Technology and Medicine, London, and with widespread concern now being expressed over scale up with recombinant material, a new dedicated lab has been built to enable collaborative studies to be undertaken under conditions of large-scale Category Two containment.

The study of fluid dynamics is crucial to the performance of bioreactors and, at the Birmingham Centre, fluid dynamic studies have characterised the gas-liquid mixing behaviour of a wide range of impellers in fluids mimicking fermentation broths. Other areas of work include unique studies of the effects of fluid dynamics on animal cell lines in culture, the development of micromanipulation techniques to determine the mechanical properties of tiny animal cells, image analysis development to characterise in detail the many aspects of fungal morphology, and highly selective recovery processes.

The joint BTD/Process Engineering Committee separation processes initiative has led to a number of successes; in particular the prevention of membrane fouling, and novel separation methods such as the use of ultrasonics and electric fields.

Bioprocess monitoring and control

Finding ways to determine the state of a bioreactor on line is fundamental to improving its operation. Probes have been developed to measure variables directly, and one that measures biomass is now on the market. Much work has also been undertaken on the development of control systems for the complex conditions inside bioreactors. Techniques which have achieved success include neural networks, self-tuning controllers, and other adaptive optimisation methods.

For the future there is a need for instrumentation to measure and monitor key process parameters, to improve bioprocess economics and reproducibility, and for associated flexible real-time control systems. These developments have, as a prerequisite, a better theoretical understanding of all aspects of the bioprocess.

Future growth areas

Areas already identified as important for future research include:

- the role of carbohydrates in understanding the physiology of living systems and producing chemical feedstocks for industry;
- post-translation processing of proteins, the key to proper understanding of protein function and activity;
- applied microbial physiology both to study the factors controlling the growth of microorganisms and to identify novel organisms with commercial potential;
- research aimed at achieving a better understanding of how to process biological material, particularly process intensification (increasing product concentration), integration, monitoring and control, and waste minimisation.

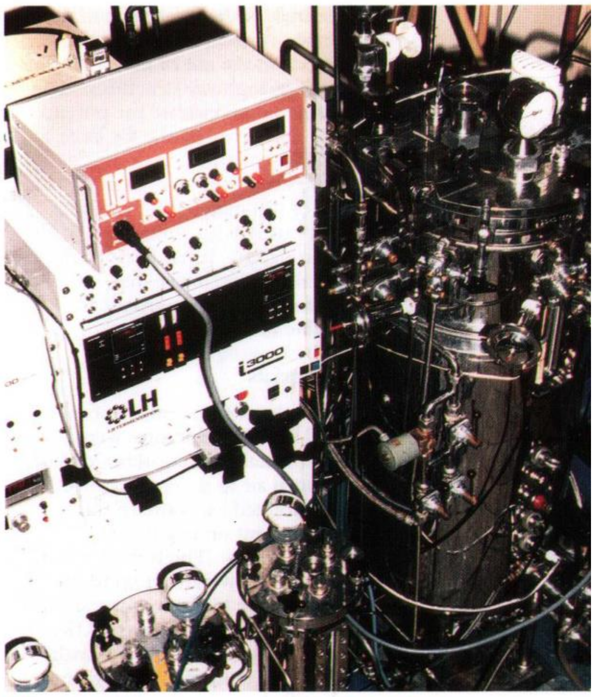
In the longer term, exciting possibilities exist in many areas for research. The search for and detection of new microorganisms and novel biocatalysts provides a challenge remote from traditional screening activities. The area of biopolymers has great potential as they can now be produced with tailor-made properties, and the ability to build in biodegradability adds a key environmental dimension. There is also the prospect of enzymes and other biological macromolecules acting as on/off switches to replace silicon technology with bio-based systems.

The future

The Biotechnology Directorate has been successful in establishing an active research community with good links with industry in a number of key areas. In the future the Directorate looks forward to a continuing role in the strengthening and expansion of its research community in order that industry may retain its competitive advantage by exploiting biotechnology into the next century.

Further details of this work are available in the Tenth Anniversary issue of the Directorate's *Biobulletin* and in the *Forward Plan* , available from the author.

Hugh Thurbon
Biotechnology Directorate
SERC Swindon Office
Telephone (0793) 411000 ext 2076



A biosensor in the research environment — an Aber Instruments "Bugmeter" in use at UCL Department of Biochemical Engineering. The Bugmeter was developed with Biotechnology Directorate support.

LINK Transport Infrastructure and Operations programme

The LINK Transport Infrastructure and Operations programme, sponsored by the Department of Transport and SERC, has now been running for almost three years and a worthwhile body of research is building up. By October 1992 about 40% of the £11.8 million available programme funds had been allocated. Approved projects are listed in the box.

There is a need to develop novel technologies to handle the consequences of the growth in demand for transportation. The research should help to create a more efficient, cost-effective and safer transport environment.

Projects are supported in four key areas:

- Road safety
- Measures to combat traffic congestion
- Environmental impact
- Improved methods of construction and maintenance of transport structures, highways and bridges.

The bulk of the research is in this last theme. A good example is the project on the use of fibre-reinforced plastic in highway structures. The aim is to demonstrate the potential of fibre-reinforced plastic for large load-bearing structures, such as pedestrian bridges or traffic sign gantries. The cost of this material is becoming competitive with aluminium, steel and concrete. It has low weight, is virtually maintenance free, self-coloured, damage resistant and capable of rapid erection.

Approved projects — October 1992

System for estimating life cycle costs.
Deep stabilisation of slopes using lime.
Use of fibre reinforced plastics in highway structures model HGV operating centres.
Diesel engine performance optimisation for reduced transient exhaust emissions.
Research into improvements in non-reflective absorbent barriers.
Chloride penetration resistance of surface-treated concrete.
Road cracking analysis by image analysis on a digital array processor.
Design and testing of bituminous mixes.
Shallow trench reinstatement.
Urban railway noise: the effects of track design parameters.
Improved matrix estimation methods under congestion.
Long-term performance of concrete repair in highway structures.
Advances in computer-aided design methods for road vehicle silencers.
The behaviour of skew masonry arches.
Parallel microscopic traffic simulation.
Stabilisation of road foundations.
Real time model-based vision system for vehicle identification.
Remote positional control of steerable moles for trenchless pipelaying.

Field trials

Throughout the summer of 1992, two 18-metre structures were tested under sustained long-term load in the open air to determine the effects of prolonged exposure to the environment on engineering characteristics. The beams, which can bear the weight of up to 60 people, were by far the largest such structures ever made in the UK. These field trials, in parallel with theoretical studies, will provide a scientific basis for the design of future innovative applications of this technology.

The effect of transport on the environment can be significant, hence the inclusion of the topic in this programme. One current project is investigating the effects of track design parameters on urban railway noise.

Many cities throughout the world are contemplating installing light rail systems to improve travel within their boundaries. However, the environmental impact of such systems is an important consideration.

Noise nuisance

Steel wheel-on-rail systems are still the most cost-effective propulsion method but the noise generated can be intrusive particularly at night. Light rail systems will become much more acceptable if this research succeeds in identifying ways in which noise from new projects could be minimised. The research will establish the relationship between mechanical parameters measured on, or close to, urban railway tracks and noise nuisance caused in the community.

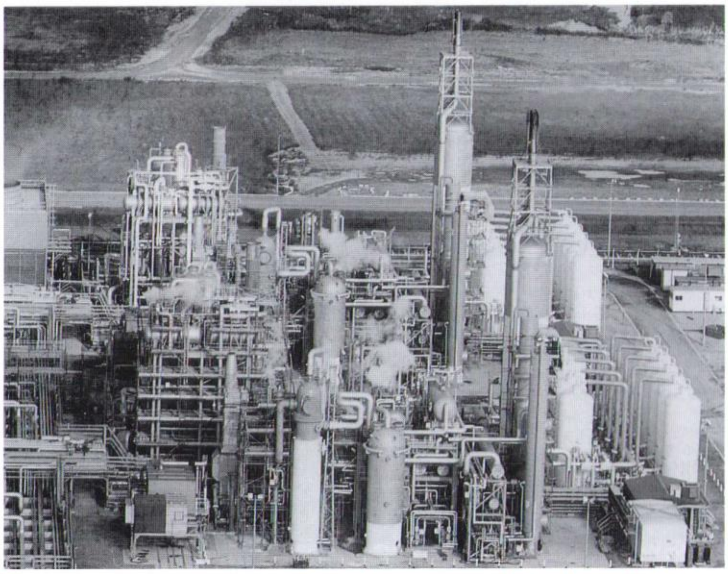
The Programme Management committee meets to consider applications quarterly and new project proposals are welcome. The sponsors welcome the active involvement of the construction industry in this LINK programme and wish it to continue. To achieve all the objectives of the programme a good balance of projects must be maintained across all four programme themes. Further suitable applications across the whole programme are required.

Closing dates for applications and further information can be obtained from:

M E White
Chief Scientist's Unit (P2/0469)
Department of Transport
2 Marsham Street
LONDON SW1P 3EB
Telephone: 071-276 5882

H Wyborn (Coordinator)
38B Heathfield
LEEDS
LS16 7AB
Telephone: (0532) 672701

Dr Andrew Rawlins
SERC Swindon Office
Telephone: (0793) 411353.



The new leading concept ammonia technology for ammonia production developed by ICI virtually eliminates sulphur dioxide emissions and reduces nitrous oxide emissions by a factor of seven compared with previous technology.

Nil emissions – the next Clean Technology research target

The joint Agricultural and Food Research Council/SERC Clean Technology Unit is preparing its next major target in research towards nil emissions in process industries.

Liquid, solid and gaseous waste materials are inevitably generated during the manufacture and use of any product. Apart from creating potential environmental problems, wastes not only represent losses from the production process of valuable raw materials and energy, but also require significant investment in pollution control practices. Many of these "end-of-pipe" fixes offer little scope for recovery and transfer the waste from one environmental medium to another, often in a highly diluted form.

The best solutions avoid, eliminate or reduce the waste at source, usually within the confines of the production unit, or allow re-use or recycling of the waste for benign purposes. The Unit is identifying the research agenda for:

- **elimination** – the complete elimination of waste through the introduction of new "clean" processes;
- **source reduction** – the avoidance, reduction or elimination of waste, generally within the confines of the production unit, through changes in industrial processes or procedures. This can occur through technological changes, for example in reaction engineering, separations and recycle, process operations and utilities; by input material changes, such as raw materials solvents; by product changes, for instance reduction of modification of packaging; and generally through good operating practices and good housekeeping;
- **recycling** – the use, re-use and re-cycling of waste for the original or some other purpose such as input material, materials recovery or energy production.

The definition and scoping study for the area is currently being finalised in preparation for its launch and issue to the academic research community in March 1993. It will:

- outline the concept of waste minimisation and its application to the prevention or reduction of any "waste"; and
- identify the barriers and the most promising academic research directions, as a guide to intending applicants for funding.

The study will identify not only the scientific and engineering challenges but also the socio-economic issues which require attention. This will overlap with discussions currently in progress with the Economic and Social Research Council on the scope of a research target in Life Cycle Analysis and the costing of environmental effects - an area vital for any clean technology.

As usual, intending applicants are encouraged to send the Unit a short outline of their research proposals. Staff will then give advice on whether and how to formulate a full proposal.

This new target complements the three existing research targets: harnessing photosynthesis, clean synthesis of effect chemicals, and farming as an engineering process, launched in February 1992. The Unit is also backing generic research on "clean" combustion, electrochemistry, and analysis and measurement techniques.

For further information on the Clean Technology Unit, addition to the mailing list for the forthcoming waste minimisation report and copies of the reports on the current research targets, please contact:

Eric Winiarski
SERC Swindon Office,
telephone (0793) 411492

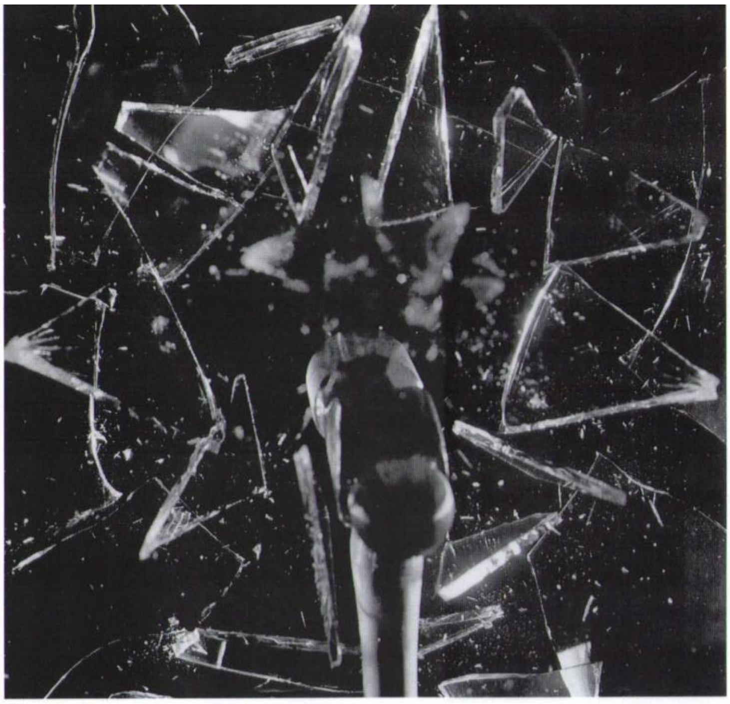


Figure 1: Hammer impact on glass.

Transparently obvious?

It is one of the oldest materials that man has developed. It is a very modern material, used to support the latest methods of digital communication. It has been used to startling effect in architecture and in sculpture; it can also correct our sight. It is glass. Tony Buckley and Neville Greaves of Daresbury Laboratory throw new light on its atomic structure.

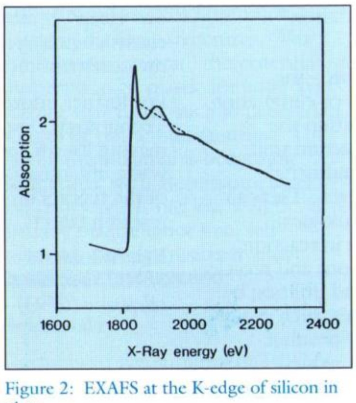


Figure 2: EXAFS at the K-edge of silicon in glass.

Glass is a complex mixture of silica and alkali or alkaline-earth metal oxides. Everyone knows that glass is hard, brittle and transparent - the photograph in figure 1 demonstrates this dramatically. Less well known is that oxide glasses conduct electricity through the transport of ions. All of these properties come from the atomic structure of glass, a non-crystalline amorphous network more like that of liquids. However, models of the atomic structure of glass have failed to account for all these properties. Researchers investigating the structure of glass using the Synchrotron Radiation Source and computing facilities at SERC's Daresbury Laboratory have recently come up with a more comprehensive explanation.

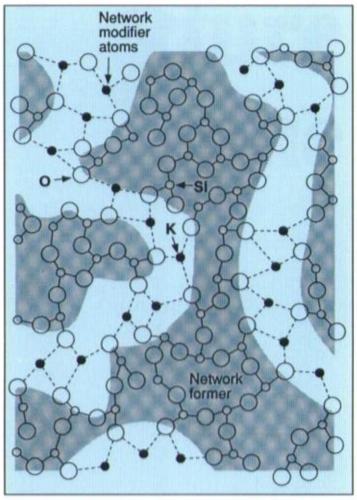


Figure 3: Schematic of Modified Random Network.

The Synchrotron Radiation Source (SRS) at Daresbury has allowed the detailed atomic structure within glass to be determined. The EXAFS (Extended X-ray Absorption Fine Structure) technique uses the fact that different atoms can be ionised by being made to eject one or more electrons upon absorption of electromagnetic radiation at different wavelengths. As the energy of the radiation increases above the ionisation threshold, oscillations in the absorption spectrum of the atom may be seen (figure 2). These are caused by the scattering of the

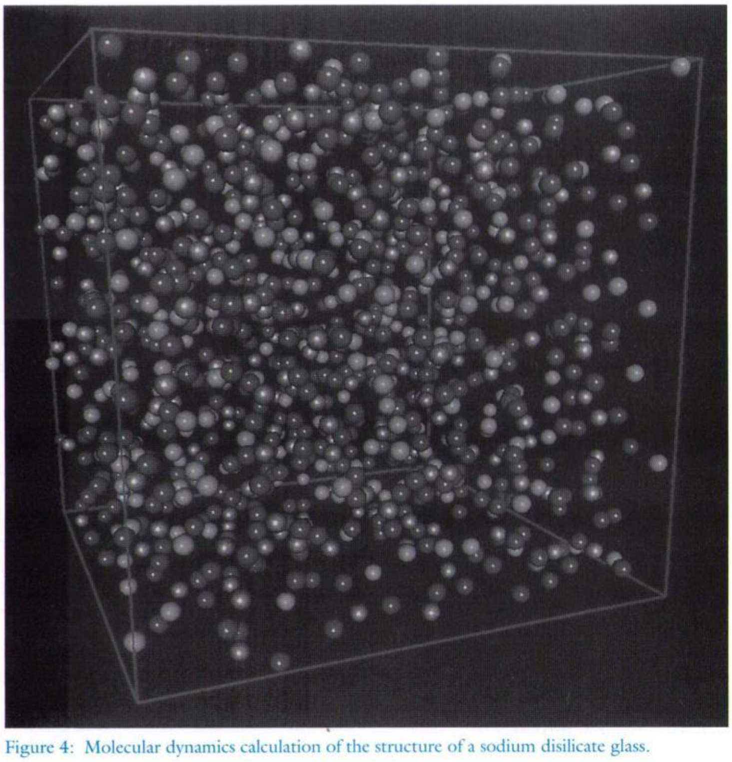


Figure 4: Molecular dynamics calculation of the structure of a sodium disilicate glass.

electron emitted from the atom under study by the different atoms that surround it. Study of these oscillations gives information on the types, numbers and distances of the neighbouring atoms. Since the SRS allows the incoming X-rays to be tuned to a particular wavelength, it is possible to study each different type of atom within the glass individually. A detailed picture of the atomic structure within the glass can then be constructed from an analysis of the absorption data from each type of atom.

Armed with their EXAFS data, researchers from Daresbury and Keele, Leicester, Manchester and Rochester (New York) Universities have constructed a model known as the Modified Random Network (MRN), that has proved particularly successful in explaining the diverse properties of glass. They have predicted that the structure of glass at the atomic level segregates into a mixture of network-forming regions and modified regions (figure 3). The silicate-rich component which forms the network part gives glass its hardness and transparency. Alkali oxides, the component modifiers in the glass, form channels weaving through the network. The boundaries between the two may be the weak links in the structure along which glass will crack.

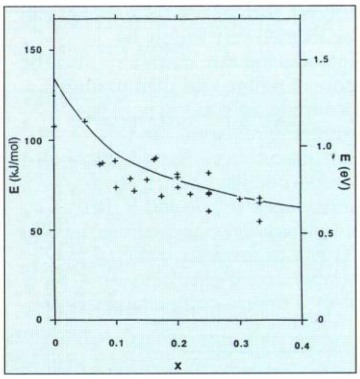


Figure 5: Activation energy for sodium diffusion in sodium silicate glasses.

The same picture also emerges in three-dimensional representations of glass structure obtained from molecular dynamics calculations. These massive arrays of atoms are generated by computers replicating the formation of glass from the liquid state — the mathematical interactions between the various types of atoms in the calculation mimic the chemical forces between the atoms in glass. The structure of sodium disilicate glass created in this way is seen in figure 4 and the clustering of sodium atoms (here depicted by yellow spheres) can clearly be seen. These connect to provide the routes allowing the conduction of ions.

From this knowledge of the specific structure of glass, obtained from EXAFS experiments and confirmed by computer simulation, the activation energy for the diffusion of alkalis has been calculated for the first time and compared directly with experiment. The activation energy — the barrier facing mobile cations as they diffuse through the glass — falls progressively as the concentration of alkali in the glass increases and this is accurately predicted as figure 5 shows.

Where more than one alkali ion is present, such as in sodium rubidium silicate, conductivity is dramatically reduced compared to glass containing only a single alkali ion; this is known as the 'mixed alkali' effect. Figure 6 shows that the intimate mixing of the sodium atoms (blue spheres) and oxygen atoms (red) that form the structural network of the glass allows each to impede the passage of the other through the glass network. As a result, activation energy is increased and conductivity declines markedly.

This combination of empirical and theoretical approaches, using the SRS and the advanced computing facilities at Daresbury Laboratory, has improved our understanding of structure-property relationships in glass. The MRN concept has facilitated this and opened the way for tackling more complex problems in the glassy state. These ideas may be useful in developing chemically toughened glasses and corrosion-resistant glasses for containment of nuclear waste.

Transparently obvious? Far from it!

A G Buckley and G N Greaves
Daresbury Laboratory

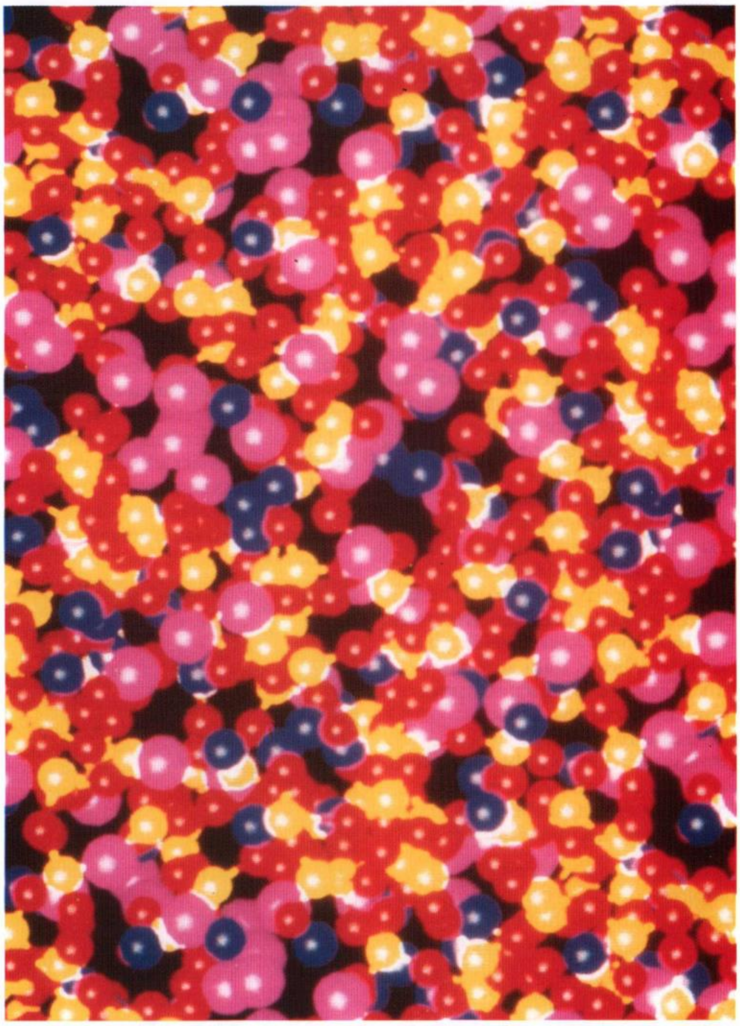
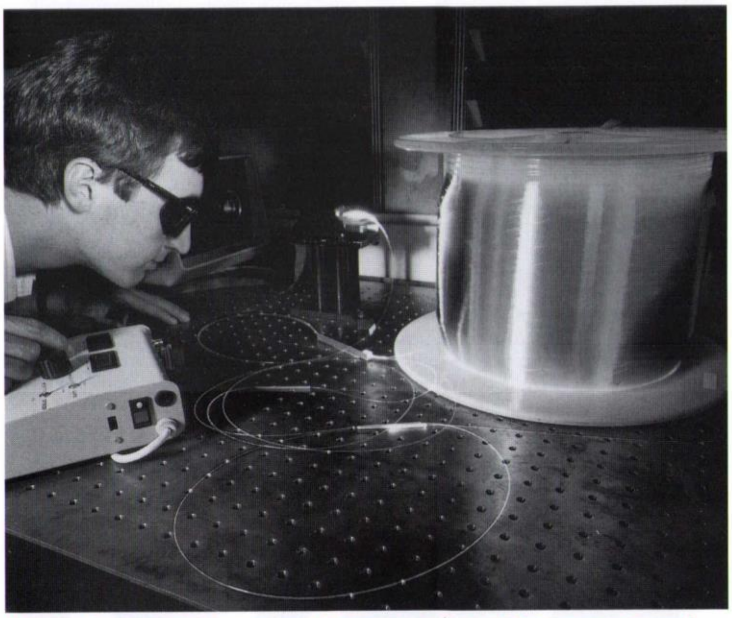


Figure 6: Molecular dynamics calculation of the structure of a sodium rubidium silicate glass.

Optical fibre amplifiers



Dr Richard Laming, Royal Society Senior Research Fellow, in the Optoelectronics Research Centre, studying the properties of the erbium fibre amplifier.

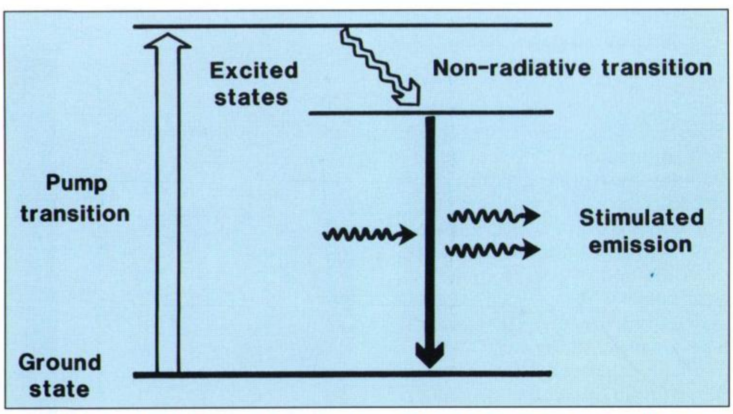
Optical fibres have been developed to a high degree of sophistication for information transmission and can now be regarded as high-quality light conductors. Compared with copper coaxial cables, which have a bandwidth of 20MHz or so over distances of 3-5km, they can have almost infinite bandwidth at repeater spacings of several hundred kilometres, with the additional advantages of being small, light in weight, flexible and immune to electromagnetic interference. Optical fibres have transformed telephone networks, already carrying 80% of British telephone traffic, and by 2015 the entire Japanese telephone network will be "fibred", so enabling it to carry telephone, data and video (TV) into every home. Copper wire and electrons, and increasingly satellite communication, will be displaced by fibres and photons, writes Professor Alec Gambling of Southampton University.

In communication terms, and despite their massive impact, optical fibre systems were until recently still at a relatively primitive stage of development. The only operation possible was the transmission of information optically from one point to another. To modify or amplify the signal, it had to be converted back to electrical form for processing and then reconverted into light — a very clumsy and inefficient method.

However, in 1987 a paper published by the Optical Fibre Group at Southampton University provided a further massive stimulus to the application of optical fibres by describing work (carried out under a rolling grant from SERC) which culminated in the demonstration of the first fibre device capable of amplifying optical signals. The paper followed from earlier Southampton work under the same programme which had developed methods for introducing rare-earth atoms into the core of an optical fibre. When a rare-earth ion is irradiated by light of a suitable wavelength, its internal energy can be increased to an excited (metastable) energy state. This 'exciting' radiation is usually referred to as 'pumping' radiation. Normally the excited ion releases its excess energy spontaneously in the form of a photon of light of a characteristic (signal) wavelength.

Optical amplification

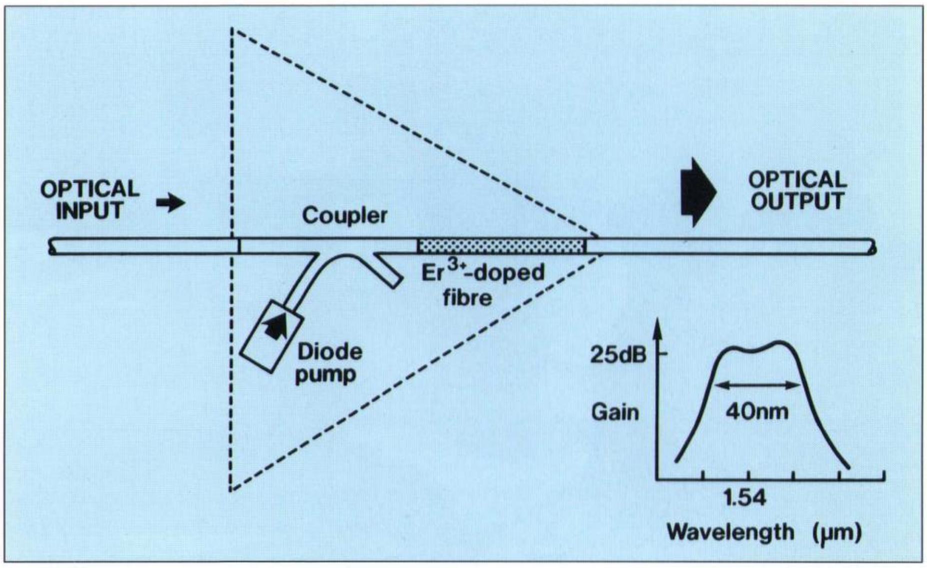
On the other hand, if another photon at the signal wavelength interacts with the excited atom then the emission of the signal photon from the atom is triggered (or stimulated) by the incoming photon. So from one input photon at the signal wavelength and an excited atom, after the interaction there are two photons and a de-excited atom. In other words we have doubled the number of photons — optical amplification has occurred. This doubling means that the signal-light intensity steadily increases along the length of the amplifying fibre. It follows that an optical amplifier can be formed very simply by introducing rare-earth ions into the core of a fibre and then passing pumping light along it. The pumping radiation can be introduced from the side through a simple coupler. Signal light introduced at one end is then amplified as it travels along the fibre. The fibre amplifier is therefore a simple device of a metre or so of doped fibre, a coupler and a laser



Simplified energy level diagram of the erbium ion. Radiation at the pump wavelength raises the ion energy into a range of excited states which decay rapidly to a metastable level. An input photon of the appropriate wavelength can stimulate a transition back to the ground state with the associated creation of a second photon of equal wavelength and phase.

diode to provide the pump radiation. It is potentially cheap, highly reliable and easily spliced into the fibre transmission line.

In particular, the amplifier formed by doping the fibre core with erbium is having a major impact on all aspects of optical fibre communications and signal processing. The erbium fibre amplifier is a remarkable device with many of the properties of a perfect optical amplifier. It has a high gain, more than 50dB, a noise performance close to the theoretical minimum, low cross-talk between signals of different wavelengths, is capable of output powers well over 1mW and, by a most fortuitous coincidence, operates at the wavelength of 1.5μm where the attenuation of optical fibres is a minimum and the bandwidth can be made exceedingly large. By suitable amplifier design, the quantum efficiency can be close to 100%, which means that almost every pumping photon can be turned into a signal photon. A further, highly practical, advantage of the erbium fibre amplifier is its stability, which arises because the pumping energy is stored in the excited (metastable) state which acts as a form of reservoir from which energy can be drawn when required. The gain is therefore largely independent of both the wavelength and the pumping power over quite large ranges and when saturation begins to occur the gain falls relatively slowly.



Schematic diagram of an optical fibre amplifier. The input signal, along with pumping radiation, enters one end of the doped fibre and is amplified during propagation along it. The combination of fibre coupler and doped fibre is spliced into the main fibre transmission line. Gains of over 50dB (x100,000) can be obtained. A linewidth of 40nm corresponds to a bandwidth of 5000GHz.

Erbium fibre amplifier

- Operates at 1.5μ
- High efficiency (93%)
- Large gain (50dB)
- Large bandwidth (5000GHz)
- Low noise (noise figure 3.1dB)
- High power (0.5cw)
- Laser diode pumping
- Easily spliced to transmission fibre
- Large dynamic range (-50dBm to +10dBm)

The amplifier bandwidth is also large, more than enough to satisfy most present system requirements. This large bandwidth also enables it to be turned into a fibre laser capable of generating a train of pulses, as short as a few tens of femtoseconds in duration. Any amplifier can be turned into an oscillator by applying the appropriate feedback. Thus if the input and output communication fibres to the amplifier are removed and replaced with mirrors then the fibre amplifier becomes a fibre laser. Alternatively if the output end of the amplifier is connected to its input, then a ring laser is created and it is this configuration, with appropriate modifications, which has given rise to femtosecond and soliton pulse generation. However, the topic of the new fibre lasers, although as interesting as that of fibre amplifiers, is so important that it would deserve a separate article.

Transatlantic cable

The fibre amplifier can be used in many different ways; indeed, it will have as strong an influence in communications in the 1990s as the transistor did in the 1950s. For example, existing electronic repeaters in fibre communication systems are being replaced by fibre amplifiers to provide a substantial reduction in cost, improved reliability and much more flexible operation. A transatlantic cable is planned for 1995 containing only optical amplifiers. A similar cable across the Pacific planned for 1996 will carry 600,000 simultaneous telephone circuits, 150 times more than the last copper transatlantic cable! Communication cables can now carry many television channels simultaneously as well as data and telephone traffic. The use of satellites for point-to-point communication will gradually be phased out. By multiple circulation around a 500km loop, with amplifiers spaced at 50km intervals, soliton pulses have been propagated over a distance of 1,000,000km at a rate of 10Gbit/s. Terrestrial optical fibre transmission can now take place over unlimited distances with almost unlimited bandwidths.

In local networks British Telecom has recently shown that erbium fibre amplifiers would enable a single source to provide 12 simultaneous TV channels to 39,000,000 homes over a radius of 500km — every home in the UK could therefore be supplied with all its telephone, data and television requirements from just one transmitter.

Many other applications can now be anticipated, ranging from telecommunications, optical sensors and signal processing, to a study of optical interaction in a range of physical, chemical and biological media and especially in the development of nonlinear optics. Research is continuing in the Optoelectronics Research Centre at Southampton to develop fibre and planar amplifiers (and lasers) which will become the basic building blocks of future optical systems.

Professor W A Gambling
Optoelectronics Research Centre
Southampton University/University College London

The optical fibre amplifier was invented at Southampton University and developed with SERC funding under the JOERS (Joint Opto-Electronics Research Scheme) in collaboration with Plessey (now GEC-Marconi Limited), STL (now BRN (Europe) and British Telecom.

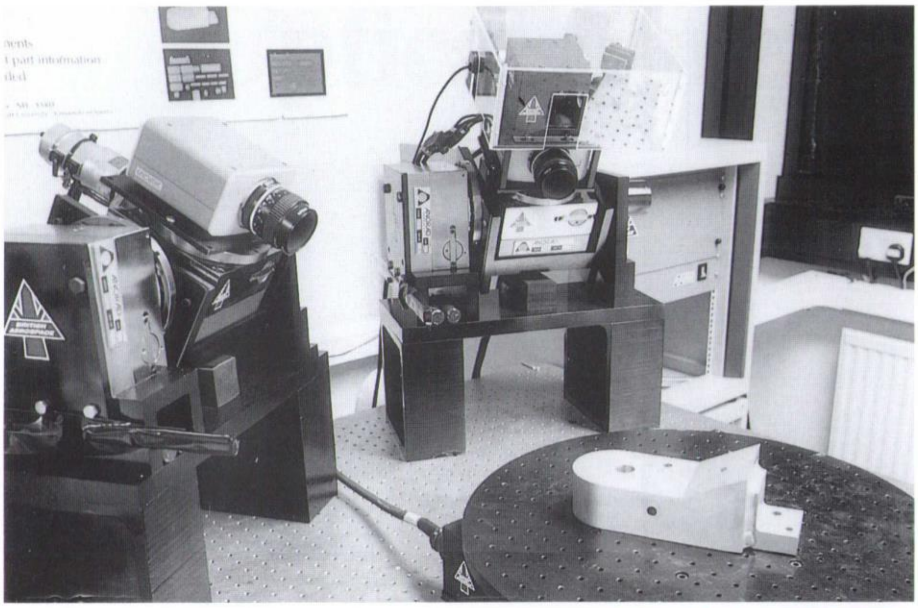


Figure 1: Laser striping of component.

Location and inspection using depth data

With the aim of achieving more widespread adoption of automatic inspection systems within UK industry, a consortium of industrial and academic partners is currently developing a system to perform inspection of three-dimensional objects through the use of depth data obtained from a laser scanner. The system is described here by Dr Ian Risk and Dr John Anderson of British Aerospace.

Rising costs, and the demand for shorter production life cycles, increased output and higher levels of quality assurance are forcing companies to include in their corporate strategy an increasing amount of automation in their production facilities in order to retain or improve their market position. As part of this strategy, manufacturers are now starting to employ automated inspection systems based on machine vision as part of automated production cells. These systems can help the manufacturer to achieve higher levels of quality assurance at acceptable cost by:

- reducing manning costs
- increasing throughput
- accurate and consistent inspection of components
- data logging of errors to enable faults to be readily determined.

The systems however need to be flexible to enable the manufacturer to change or modify the object under inspection in order to match developments in the market, and cope with small batch production of a wide range of parts. This is particularly important in the aircraft industry, where small batch production is the norm, and so the time taken to adapt to a new type of component is critical to the success of an inspection system.

Many of these inspection systems are based on the use of television cameras which capture an image of the object under inspection and the image is then processed by a computer. The information generated is then used to make measurements of the object automatically to see if it complies with the specifications set by the designer. The techniques have proved highly successful in some applications, especially where the two-dimensional camera image is used to measure a two-dimensional object such as an integrated circuit wafer.

Three-dimensional data

However, for some other applications, three-dimensional objects such as metal castings need to be measured, and for these, three-dimensional information, or depth data, is required.

So far, the development of three-dimensional inspection systems has been limited to Coordinate Measurement Machines (CMMs), which use a touch probe to make measurements on the surface of objects. CMMs, however, take a considerable amount of set-up time, they are slow to use and only a restricted number of test points are obtained. Overcoming these problems through the use of automated inspection systems required developments in sensors to produce depth data and the software to process and interpret those data.

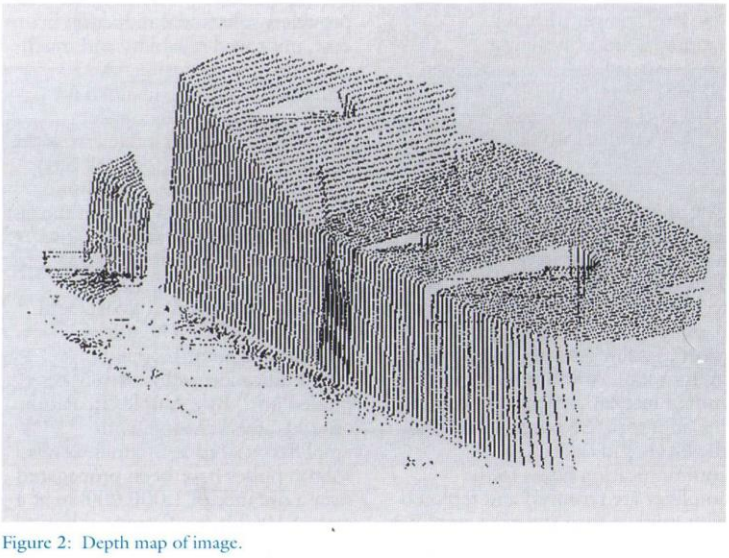


Figure 2: Depth map of image.

Figure 3: Depth map after segmentation.

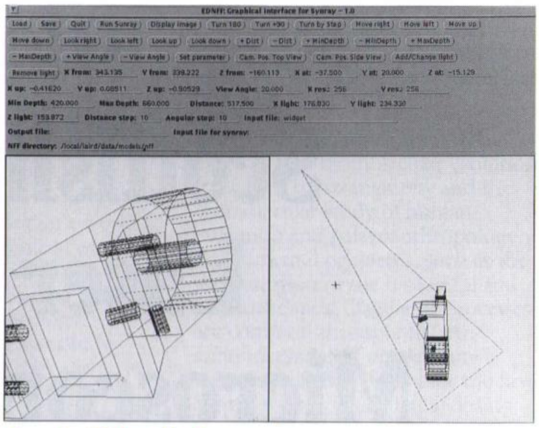


Figure 4: CAD model of component.

To tackle this need a collaboration between UK industrial and academic partners has been developing an inspection system, known as LAIRD (Location And Inspection with Range Data), that will demonstrate the use of depth data as input to an automated inspection process which will be faster than conventional CMM systems.

LAIRD

The LAIRD system obtains depth data is from two sources, a laser striping system which is used to detect and locate the object, followed by a more accurate moiré fringe system. The laser striping system is made up of two cameras which view the object from different angles, together with a laser (figure 1) which scans a stripe of light over the object; this is recorded by the cameras. The 2-D images acquired by the cameras are then processed to form a depth map of the image (figure 2), giving a 3-D reconstruction of the object. Once the object is located, the moiré fringe sensor is used to obtain more accurate 3-D data on certain areas of the object that require detailed inspection.

The depth data is then processed in a number of stages using algorithms contained within the computer which controls the operation of the system. The first process is to segment data points into regions which can in turn be used to identify the surfaces of the object under inspection (figure 3). Once these features of the object have been identified they can be matched against a database of objects held in the memory of the computer in the form of computer-aided design models (figure 4). Once matched, the computer can perform a comparison of the image obtained from the sensors and the 'perfect' image from the CAD model in order to see if the dimensions of the object are within the set tolerances or if there are any flaws present (figure 5). The selection of algorithms to perform these operations is controlled by a knowledge-based system which selects the most suitable algorithm for each stage based on the quality of the image or the type of component under inspection.

Reduced cost

Another potential use for the system currently being investigated is the automatic generation of CAD models from real objects, which would enable the rapid production of CAD data from prototype models at greatly reduced cost.

The project, which is supported by SERC's Information Technology Directorate, is a collaboration between British Aerospace (the managers), BAeSEMA Ltd, National Engineering Laboratory, and Heriot-Watt, Edinburgh and Surrey Universities.

I C Risk and J Anderson
Sowerby Research Centre
British Aerospace plc

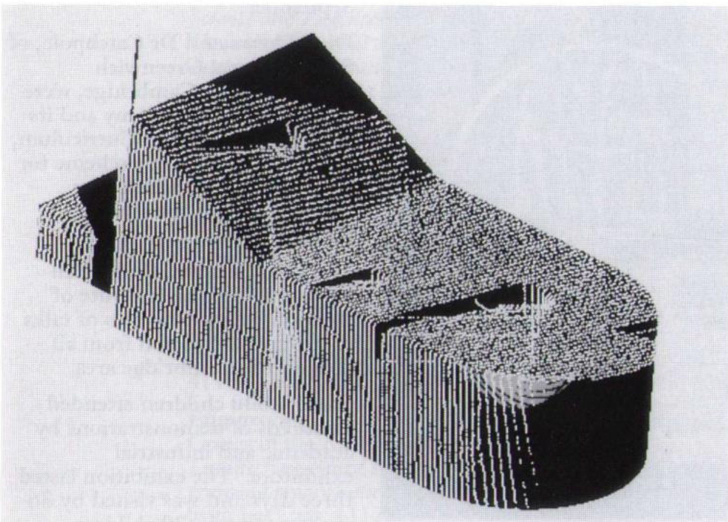


Figure 5: Depth data matched to CAD model.

Scottish Confocal Laser Scanning Microscope Facility

A £140,000 grant from SERC's Biological Sciences Committee in 1991 enabled the School of Biological and Medical Sciences at St Andrews University to set up the Scottish Confocal Laser Scanning Microscope Facility. Biologists from other academic institutions are welcome to visit the Facility, to use it or to evaluate the potential of the technique.

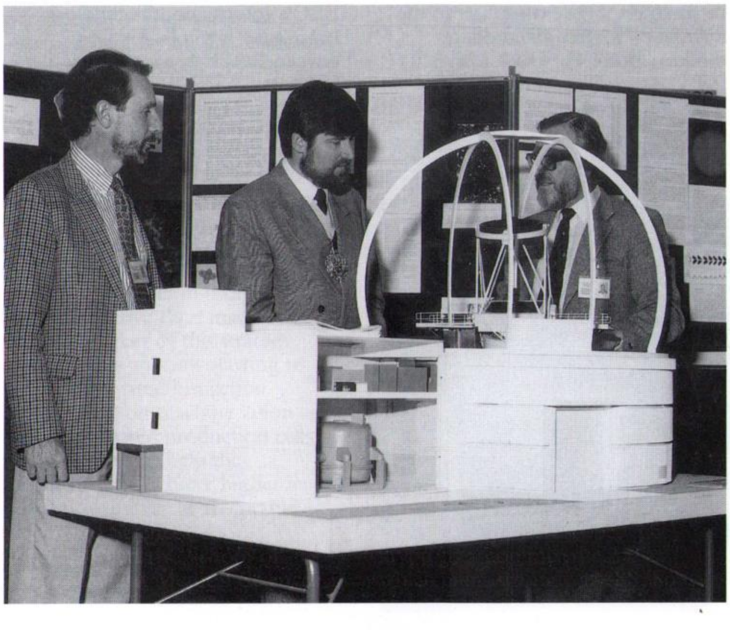
The facility uses a Bio-Rad MRC 600 Series Laser Scanning Confocal Imaging System in conjunction with a Nikon Diaphot Inverted Fluorescence Microscope. The krypton/argon mixed gas laser, which emits strongly at 488, 568, and 647 nm, is suitable for use with fluorochromes which are excited by wavelengths in this range, such as fluorescein, lucifer, yellow, rhodamine and texas red.

The two-channel detection system facilitates analyses of doubly labelled preparations and also merging a confocally acquired image with a simultaneously recorded transmitted light phase-contrast image of a specimen. Immunogold stained specimens can also be examined confocally. The motorised focus control system and Thru-View software can be used to analyse serial sequences of optical section images, such as display and rotation of three-dimensioned structural reconstructions, or display of selected X-Z sections in a 3-D image file. A 35 mm camera attached to a high-resolution flat screen video monitor is used for black and white image photography; a Sony UP 5000P video printer provides pseudocolour prints. Stationary specimens with thicknesses of up to 2 mm can sometimes be monitored confocally depending on the specimen support system used and the resolution required.

An additional workstation for analysis and manipulation of previously acquired images stored on optical disc cartridges is sited in the University's Gatty Marine Laboratory. Accessories for microinjection and sophisticated modes of calcium detection are not yet available.

Visits to the Facility can be arranged by contacting Professor John Tucker, Bute Medical Building, St Andrews, Fife KY16 9TS. Telephone (0334) 76161 ext 7230; fax (0334) 78399.

Astronomy for children



The Mayor of Cambridge, Councilor Barry Gardiner (centre) finds out what's new in astronomy from Dr Peter Andrews (right) and Dr Robin Catchpole, at the eighth Physics at Work Exhibition held in the Cavendish Laboratory in September.

Dr Andrews and Dr Catchpole, of SERC's Royal Greenwich Observatory at Cambridge, were talking about astronomy and its place in the National Curriculum, as well as the Mayor's scheme for providing useful activity for children during the school summer holidays.

The two scientists, along with students from the Institute of Astronomy, gave a series of talks to groups of children from all around the Cambridge area.

Some 1,600 children attended hundreds of demonstrations by academic and industrial exhibitors. The exhibition lasted three days and was visited by 36 groups of up to 20 children.

Funding for ancient clues

The field of ancient biomolecules research, has been given a boost thanks to a £1.6 million award from SERC and the Natural Environment Research Council (NERC) who are contributing equally to fund a five-year programme starting in 1993.

The Ancient Biomolecules Initiative (ABI) will be directed by a joint panel reporting to SERC's Science-based Archaeology Committee (SBAC) and NERC's Earth Sciences Committee, and will provide support additional to baseline activity in the area by both councils. A part-time coordinator is to be appointed. Interim coordination will be provided by the SBAC coordinator.

The ABI builds on Britain's world lead in 'ancient' biomolecules research, which has been fostered by SBAC and NERC's Special Topic in Biomolecular Palaeontology. Important recent advances have included analysis of DNA and protein from archaeological bone, DNA and lipids from bogs and other plant remains, characterisation of food residues from ancient pots, and the isolation of viable bacteria from four million-year-old ocean sediments.

However, much remains to be done and the potential of whole groups of organic compounds, such as polysaccharides, lipids and proteins, remains largely unexplored. ABI will seek to foster collaboration between earth scientists, archaeologists, chemists, biochemists and molecular biologists.

Three areas identified for special emphasis are biomolecular evolution, molecular biostratigraphy and the biomolecular study of human evolution and palaeoanthropology. Fundamental problems, such as the identification of the biological and physiochemical diagenetic processes are common throughout. An announcement of opportunity is being issued in February for the first annual round, which has a closing date of 1 July 1993.

For further information, contact Neil Williams, Secretary of SERC's SBAC, telephone Swindon (0793) 411261; Dr Lin Kay, NERC Earth Sciences Directorate, telephone Swindon (0793) 411521; or Dr Sebastian Payne, SBAC coordinator, telephone 071-973 3305.

Some new publications from SERC

Unless otherwise stated, all publications are available free of charge from SERC Swindon Office, telephone national code 0793 followed by the numbers given below.

SERC annual report
Copies of the *Annual report of the Science and Engineering Research Council 1991-1992* and of the *Factsheet and statistics 1992* are available from Janet Edwards, 411256.

SERC and the environment
Copies of a new leaflet, *SERC and the environment*, are available from Janet Edwards, as above.

Astronomy
Into the 21st century: The future direction of UK astronomy, planetary and Earth observation science: copies are available from Elizabeth Foley, 411000 ext 2063.

Engineering
Copies of the *Review of SERC Engineering Board education and training programme* are available from Les Sims, 411238.

Copies of *A process engineering strategy for the 1990s* are available from Kay Newton, 411160.

Copies of the Electro Mechanical Engineering Committee's *Grants current at 1 September 1992* are available from John Espley, 411200.

Materials
Copies of the *Review of the Low Dimensional Structures and Devices Initiative* are available from Lesley Thompson, 411479.

Calling all research sponsors
The Industrial Affairs Unit has, since its inception, wanted to offer industry the opportunity to see all the applications to SERC for research which receive the highest ranking in SERC but for which no funds are available. In an attempt to achieve this, SERC has joined with Norsk Hydro and Oakland Consultancy to produce the *Research bulletins.* This first pilot volume contains all those applications that received an alpha rating by SERC's peer review system in Summer 1992 in the areas of chemistry, processing engineering, materials and related technologies, construction and environmental civil engineering. Academics are, of course, given the choice of having their applications included in the Bulletins or not.

Copies of the *Hydro Oakland research bulletins, in association with SERC,* are available from Oakland Consultancy, 10 Jesus Lane, Cambridge CB5 8BA; telephone (0223) 300475.

Readership survey

Thanks to all those who took part in the readership survey in the autumn issue of *SERC Bulletin.* There was a tremendous response and reading the survey forms will keep us busy for some time.

Meeting of young minds

Britain's school system may not bring the best out of the country's promising young scientists, says a beneficiary of the Holmes Hines Memorial Fund.

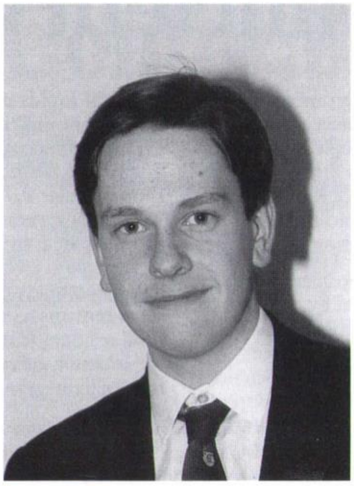
Bernard Kelly, a student at St Edward's College, Liverpool, was sponsored by the fund to take part in the 34th London International Science Forum, which he described as "a truly memorable event".

One of the benefits of the forum was that Bernard, who is 18, met young student scientists from around the world at the event and was impressed by the standard of their knowledge and understanding. It was an eye-opening experience, as he explained.

"The system here is too restrictive and does not allow freedom to explore science to a high level at an early age. Highly inquisitive youngsters in other countries seem to get a much better deal from their education. It seems the UK is losing its flair for science and the cause appears to be the education system."

Why? Bernard reckons that GCSE examinations have led to a lowering of standards and the "watering down" of some A level courses.

Most of the science forum lectures and seminars took place at the Institute of Electrical Engineers, in London, and there were also visits to Cambridge University, GEC's Hirst research centre and the Mullard Space Science Laboratory.



Bernard Kelly

There were six main lectures, which Bernard said ranged from "excellent to superb". There were also seminars on space astronomy and optical fibre technology.

The former covered X-ray and gamma-ray astronomy, which Bernard found particularly fascinating as he aims to study astrophysics at university. Students also delivered 15-minute lectures on subjects they had studied in detail. Bernard's only criticism was that a quarter of an hour was not long enough for the young scientists to develop their arguments.

His own paper, on amateur telescope-making, one of his hobbies, was less hi-tech than those of his colleagues and so went down a little better than most.

Bernard, who is in his final year at St Edward's, preparing for A levels in Further Maths, Physics and Chemistry and an AS level in Theology, said that attending the science forum ranks among the best experiences of his life. "I would strongly advise anyone not to miss the opportunity."

What conclusions did Bernard draw from the forum? First, that science cannot hope to answer all mankind's questions; that Britain's examination system may be failing young scientists; and that young people of different races and creeds can live together in friendship and harmony, if only for the duration of the forum.

The Holmes Hines Memorial Fund provides annual prizes, scholarships, exhibitions or research grants , the incidental expenses of visiting scientists, the purchase of scientific apparatus and equipment and funds for "such other purposes for the advancement of scientific knowledge as the council shall select."

It can be used to help individuals to achieve their scientific aspirations and to sponsor activities related to science for which public funds are not available.

Applications for awards for this fund should be made to the Council's Finance Officer, P S Maxwell, SERC Swindon Office.

Any queries should be addressed to Mrs Sue Toolen, Finance Division, Swindon Office.

Researchers share prize

Two researchers have been named as joint winners of this year's Maxime Hanss prize.

The £7,000 prize is to be shared by Dr Anthony Watts, the C W Maplethorpe Fellow at St Hugh's College, Oxford, who is a lecturer in biological sciences and chairman of SERC's Membrane Initiative Panel, and Dr Nicholas van Bruggen, a lecturer in biophysics at the Royal College of Surgeons.

Commemorating the life of biophysics researcher Maxime Hanss, the prize is awarded to British and French scientists in alternate years for collaborative projects. It was created by his mother, Mrs Beatrice Hanss, who is British by birth and who wanted to establish a Franco-British memorial to her son.

The award was announced by SERC and its sister organisation in France, the Centre National de la Recherche Scientifique on 30 October.

Both winners will be using their share of the prize money to further Franco-British research projects in which they are involved.

SERC enquiry points

To make it easier to find the right person when you telephone, we have updated our list of key contact points. Except where otherwise stated, all numbers are at SERC Swindon Office. The national code is 0793 followed by the number shown. The central fax number is Swindon (0793) 411400.

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Further addresses appear on page 2.

Dr Tom Bradshaw explains the workings of a refrigerator which is used to cool infrared detectors in space.

Space for the next generation

The next generation had a chance to see the latest developments in space research when Rutherford Appleton Laboratory put on an exhibition to celebrate International Space Year. Nearly 1,000 children from 31 schools visited the RAL exhibition, entitled *Space: The Next Generation*, between 7 and 9 October.

The main emphasis was on showing the work of the Space Science Department at RAL. Children were able to visit working areas, talk to staff involved in space projects and ask questions.

Many of the exhibits showed space facilities built up at RAL, so the children were able to watch actual work in progress. Each tour lasted three hours.

Aerospace companies contributed displays and exhibits and items related to space research were loaned by the Science Museum.

The three-day event involved guided tours of 20 exhibit areas, where the research work is normally carried out. For safety reasons the children visited in groups with an adult from the school and a guide from RAL.

There were two competitions for the children to take part in. One involved Earth observation, answered interactively on a computer, the other was based on questions from the whole exhibition.

The RAL team involved in the exhibition were pleased with the children's enthusiasm and interest and by the appreciation expressed by the schools afterwards. Local newspapers, radio and TV covered the event and interviewed some of the children and RAL staff.

Dr Roger Emery, of the Astrophysics Division of RAL's Space Science Department, said that the exercise was a rewarding experience for all involved, whether students, teachers or staff. "We hope to have fired the imagination and enthusiasm of some of the children for a career in science and technology," he said.

Children use a computer to answer questions about the Earth's environment, with pictures from a satellite. The demonstrator (left) is Dr Jo Murray.