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SCIENCE & ENGINEERING RESEARCH COUNCIL

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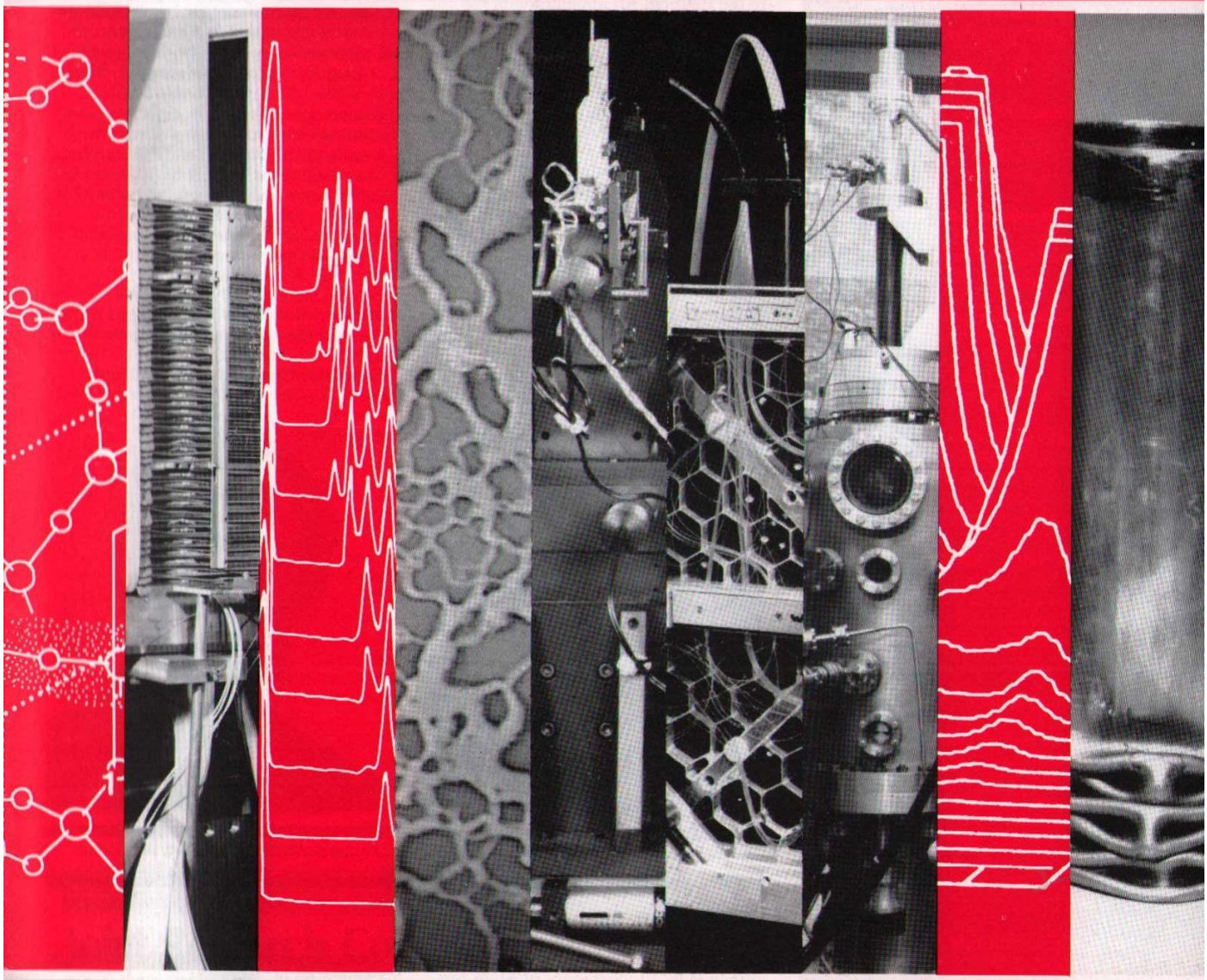

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IN THIS ISSUE

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

Establishments of the Science and Engineering Research Council

SERC Central Office
Polaris House, North Star Avenue
Swindon SN2 1ET
Telephone (0793) 26222

SERC London Office
160 Great Portland Street
London W1N 6DT
Telephone 01-636 8955

Rutherford Appleton Laboratory (RAL)
Chilton, Didcot, Oxon OX11 0QX
Acting Director Dr P R Williams
Telephone Abingdon (0235) 21900

Daresbury Laboratory
Daresbury, Warrington
Cheshire WA4 4AD
Director Professor L L Green
Telephone Warrington (0925) 603000

Royal Greenwich Observatory (RGO)
Herstmonceux Castle
Hailsham, East Sussex BN27 1RP
Director Professor A Boksenberg FRS
Telephone Herstmonceux (0323) 833171

Royal Observatory, Edinburgh (ROE)
Blackford Hill, Edinburgh EH9 3HJ
Astronomer Royal for Scotland and
Director Professor M S Longair
Telephone 031-667 3321

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

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Front cover

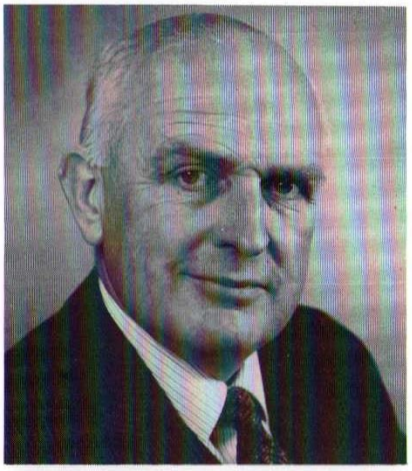
Details from illustrations on (left to right) pages 19, 18, 14, 21, 9, 7, 10, 13 and 28.

New Council members

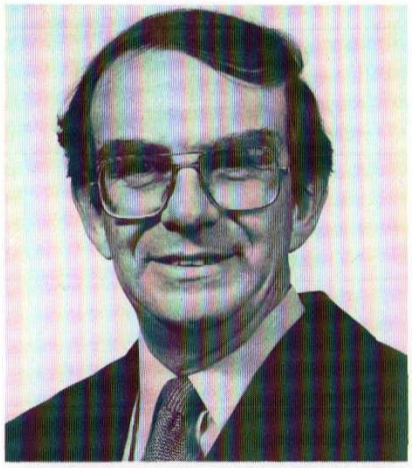
Mr Kenneth Baker, Secretary of State for Education and Science, has appointed two new members and re-appointed one other to the Science and Engineering Research Council. The new members are Dr H D Law and Professor J M Thomas, who replace Mr Geoffrey Hall and Professor James Turner. Professor Sir Richard Norman has been re-appointed to the Council. All appointments run for four years from 1 August 1986.

Dr Harry Law has been President of Portsmouth Polytechnic since 1982. After gaining a PhD in Organic Chemistry from Manchester University, he was awarded a Commonwealth Fund Fellowship to work in the Cornell Medical School in New York. He later spent five years in the pharmaceutical industry with Miles Laboratories Ltd. Dr Law's appointments have included Head of Chemistry and Biology and Chairman of the Faculty of Science at Liverpool Polytechnic; Depute Director of the Glasgow College of Technology and founder Director of Preston Polytechnic. He is the immediate past Chairman of the Committee of Directors of Polytechnics and is Chairman of the Polytechnics Central Admissions System. He is the author of a book *The Organic Chemistry of Peptides* and a large number of research papers.

Professor John Thomas FRS was appointed Director and Resident Professor of Chemistry of the Royal Institution of Great Britain and Director of the Davy-Faraday Laboratories in 1986. He had previously been Head of Physical Chemistry at Cambridge University following nine years as Head of Chemistry at the University College of Wales, Aberystwyth. He has held visiting appointments in eight overseas countries and numerous distinguished awards for his work on catalysis and the chemistry of the solid state. Among his publications he has co-edited, with M W Roberts, eight volumes of the Chemical Society's *Surface and defect properties of solids* and is the co-author, with W J Thomas, of a standard text on heterogeneous catalysis. He was a member of the Advisory Council for Applied Research and Development and has served on the (then) SRC's Chemistry Committee from 1976 to 1978.



Dr H D Law



Professor J M Thomas FRS

Decision on RGO move

The Council welcomed the approval in principle by the Secretary of State for Education and Science in November 1986 of its proposal to move the Royal Greenwich Observatory (RGO) from its present site at Herstmonceux, Sussex to Cambridge University.

Professor Bill Mitchell, Chairman of SERC, commented that Mr Baker's decision opened the way for formal negotiations with Cambridge on the precise siting of the new RGO building and the detailed arrangements for the move. Subject to approval by the University, he said, the move should be completed by 1990.

Detailed negotiations about the sale of the Herstmonceux site have now begun. At the same time, discussions continue with a number of organisations over the future of the equatorial group of telescopes at Herstmonceux which SERC would wish to keep in being, together with the visitors' centre. By this means, SERC aims to preserve the public interest in, and educational aspects of, astronomy within the Sussex area.

Council commentary

As well as the ordinary business meeting in October, the Council held discussion meetings on long-term policy in postgraduate training, relations with the R&D programmes of the European Community, and the working of the peer review system of assessing applications for research grants. The meetings were held at SERC's Daresbury Laboratory, which allowed Council members and invited guests to see the major facilities at the Laboratory: the Synchrotron Radiation Source, the Nuclear Structure Facility and the Computing Centre.

Peer review

Council discussed the nature of the grant support given — for example, individual grants compared with grants to groups — rather than the detailed mechanism of peer review which it had discussed on an earlier occasion. Consolidated grants to groups could be used more extensively, awarded against a submitted strategy and programme for the group, and subject to an annual and mid-term review. Visiting panels would discuss in detail with the groups at the mid-term review. The objectives in extending this approach were: to save the time of both applicants and officials in making and processing the present, larger, number of individual applications; to enable groups to present strategies; to provide face-to-face discussion in the peer review process; and to enable officials to deal with the more staff-intensive coordinated initiatives which Boards were developing.

Individual grants would continue to be an important component of the Council's grant-giving mechanisms. The Council had before it figures about consolidated grants which indicated that termination of such grants had occurred in a small, but significant, number of cases. The Council was sympathetic to these views and requested Central Office (Swindon) to bring forward a paper for consideration by the Council and Boards covering a package of proposals including mechanisms for simpler procedures for dealing with grants up to £50,000.

European Community's R&D programme

The total European Community budget for research and development has grown significantly in the past few years, and for the period 1984-87 is about 2.7 billion European Currency Units (1 Ecu = £0.73). Although the UK is already drawing benefit from its involvement, the availability of information in the academic sector in this country on current EC programmes and opportunities could be improved, and the Council has asked Central Office to explore the best means, and the effort that would be needed, to achieve these ends, taking account of the activities of UK industry and Government departments. One possibility would be for SERC to operate a service funded by club contributions from the universities.

Postgraduate training

A review of developments over the past decade showed the many different Council activities in postgraduate education and training. The major activities remained the provision of awards for PhD research students and MSc taught-course students, but there had been shifts between the subjects of instruction and in the direction of new forms of training. In terms of overall numbers, the Council reaffirmed the view in its Corporate Plan that, while there was no rational way of quantifying the training numbers, there was a case for not decreasing the present numbers (4,713 in 1985), because of the increase in technological efficiency needed to support the quality of life of an ageing population/age distribution. The mix of courses within these numbers was a matter for continuing discussion. The Council was impressed by the Integrated Graduate Development scheme, which comprises series of modular courses that allow young graduates in employment to undertake part-time postgraduate studies without disrupting their careers and with minimum inconvenience to their employers. It would seek ways of expanding this scheme with the collaboration of interested and funding bodies, and would also continue to look at novel methods of supporting graduate teaching for subjects of importance to SERC as a means of improving continuous education activities.

Studentships and Fellowships for 1987

At its November meeting, the Council decided to make available for competition next year the following numbers of fellowships:

Postdoctoral - 69
Advanced - 15
Senior - 2
Royal Society/SERC Industrial - 10

The Council's agreed provision for postgraduate studentships for next year shows a small overall decrease compared with 1986 (a total for 1987 of 4,912 awards compared with 4,967). The largest changes within the total are an increase of about 4% in one-year advanced course studentships in engineering subjects and a decrease of about 8% in CASE (cooperative awards in science and engineering). The latter decline reflects poor demand in 1986, but it is encouraging to note that the effect of having abolished closing dates for the nomination of CASE students has been very positive: more than 100 awards have been made so far to students whose applications would have been too late under the previous regulations.

The exchange rate problem

The current deficit for next year on the Council's international subscriptions, due to exchange rate moves since last year, is at present about £20 million, of which the major part relates to the subscription to CERN following the fall of sterling against the Swiss franc. The Council made a strong case to Government for compensation for the deficit and, as a result, received an additional £20 million from the Advisory Board for the Research Councils, following the 1986 public expenditure survey.

Joint Research Council/Ministry of Defence research grants

The scheme was introduced in November 1985 with the aim of supporting research, in the universities and similar institutions of higher education, which is not only of high academic quality but also likely to be relevant to defence, thereby contributing to the strengthening of both the UK science base and the defence research programme. During the first academic year (December and April grant rounds), SERC received 150 applications and awarded 55 grants, at a total cost of £4.1 million. The Ministry of Defence's contribution was £1.4 million (the figures are provisional).

Information about the scheme, including how to apply, is contained in a brochure copies of which are available from the administrative offices of academic institutions.

Major new grant approved by Council

ASTRONOMY AND PLANETARY SCIENCE

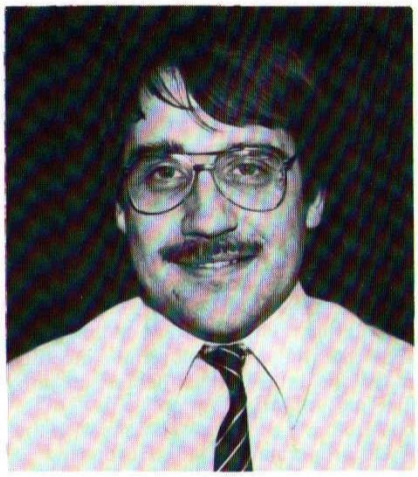
Professor G R Isaak, Dr H B Van der Raay and Dr Y P Elsworth (Birmingham University): a grant of £781,000 over four years, for applications of optical resonance scattering to solar physics.

Antibiotics and recombinant DNA

British universities and pharmaceutical companies are cooperating in a drive to maintain Britain's lead in developing a new generation of antibiotics. The aim is to use new biotechnology, including genetic engineering, to provide the basis of knowledge needed to create novel strains of moulds like *Penicillium* and other microorganisms, able to produce new antibiotics to combat resistant strains of disease-causing bacteria, and for new applications in medicine and agriculture. The results obtained will also be used to increase the production of antibiotics by rational breeding, thus bringing down the costs of medical treatment as well as adding new weapons to medical armouries.

SERC's Biotechnology Directorate and Biological Sciences Committee, and the Biotechnology Unit of the Department of Trade and Industry, together with four independent companies — Apcel, Beecham, Glaxo and ICI — will jointly fund a coordinated antibiotic research programme costing £1.4 million over the next three years. The research will be carried out at 11 universities and polytechnics.

The programme aims to go far beyond the techniques used up to now to improve antibiotic production. Instead of simply breeding more productive strains by largely empirical techniques, scientists will study exactly how a microorganism produces an antibiotic, to provide the knowledge that should allow the organism to be rebuilt, as it were, from the inside out — if necessary, adding more or new genes to step up antibiotic production or make new ones.



Dr Iain Hunter

Dr Iain Hunter has been appointed Programme Manager. He may be contacted at the Institute of Genetics, Glasgow University (telephone 041-339 8855 ext 5106).

A goblet for the Minister

Mr John Butcher, Parliamentary Under Secretary of State for Industry (right) receives an engraved goblet from Mr Tony Egginton, SERC's Director of Engineering. Presented on the opening day of Techmart '86, the goblet's main design was engraved by a computer-controlled robotic system developed by Nottingham University under a grant from SERC. With Mr Egginton are Mr Jeff Knight, the project leader at Nottingham (second left) and Mr Bill Hillier, Director of SERC's Application of Computers to Manufacturing Engineering (ACME) Directorate.

RAL Director moves out to private sector

Dr Geoffrey Manning CBE, Director of the Rutherford Appleton Laboratory (RAL), has relinquished his post to take up a position as Chairman of Active Memory Technology Ltd.

Dr Paul Williams, the present Deputy Director of RAL, has been appointed as Acting Director pending a permanent appointment to the post.

SERC Chairman, Professor Bill Mitchell said that the Council was naturally very sorry to see Dr Manning leave SERC; he had done a marvellous job during his twenty years with SRC and then SERC, and particularly in his time as Director of RAL, culminating in the successful operation of the ISIS spallation neutron source, with which he had been connected since 1976. The Council wished him every success in his new position.

Medical Engineering SPP - a postscript

A working group of the Advisory Council for Applied Research and Development (ACARD) has recently issued a report* emphasising the need for the £1 billion UK medical equipment industry to maintain its position in the world market. However, there are signs that the UK is falling behind in important areas of the business.

Several of the recommendations made in the report are particularly relevant to the SERC Materials Committee's Specially Promoted Programme (SPP) in Medical Engineering (see *SERC Bulletin* Volume 3 No 1, Spring 1985) including the requirement for coordination between the various government bodies involved in the medical equipment field, priority for medical engineering in the area of postgraduate training and the development of medical engineering research groups through future university appointments.

The report acknowledges the relevance of the SPP to the medical equipment field and recommends that total government support for research and development in this area should be substantially increased.

**Medical equipment*, an ACARD (Cabinet Office) report (HMSO publications) ISBN 011 630830 3.

New facilities for advanced research computing

At the end of 1984 the Advisory Board for Research Councils, the Computer Board and the University Grants Committee set up a joint Working Party 'to consider and report on the likely needs for advanced research computing and on the various options open to the university and research council community for acquiring, operating and providing access to the necessary services'. The Working Party was chaired by Professor A J Forty, then of Warwick University. Its report was published in August 1985 and received wide coverage in the press.* Dr Brian Davies reviews the report and subsequent developments.

The Working Party found a strong case for the provision of new advanced computing facilities, and believed that there were opportunities for advancing knowledge and understanding by computational methods in almost every branch of science. In effect the greatly increased computing power offered by present day technology has opened up a new dimension to the experimental method in scientific investigation. In many areas of science, the physical laws governing the behaviour of matter and materials are well known, but the application of these laws to complex systems which are of pressing scientific interest results in equations which require enormous computing power to solve. Examples of the areas which could benefit from this kind of computing include aircraft design, the evolution of galaxies, the chemical reactions of molecules, the physics of liquids and solids, large-scale integrated circuit design, the circulation of the atmosphere and oceans, and the design and operation of new pharmaceutical products.

The Working Party recommended that ABRC, the Computer Board and UGC should secure and allocate funds for a national facility for advanced research computing. This should comprise:

- a central installation consisting of the most powerful supercomputer available;
- an enhancement of the Joint Academic Network (JANET) to ensure good communications for remote users of this facility;
- a distributed system of other forms of advanced research computing, including special purpose machines and powerful graphics workstations to enhance local resources in selected university and research council sites;
- a national organisation of advanced research computing to ensure the effective use of these facilities, to encourage collaboration of all kinds, including industrial and overseas collaboration, and to stimulate new developments in this important area.

Given the scale of the recommendations, there has been remarkable progress towards their implementation during the past year. In February 1986, the ABRC, Computer Board and UGC agreed on a funding package which would provide a Cray X-MP/48 supercomputer to be installed at the Atlas Centre at the Rutherford Appleton Laboratory, and a less powerful Cray 1S supercomputer to be installed at the University of London Computer Centre. Both these machines have now been delivered. The Cray 1S at ULCC came into service in the Autumn of 1986. The X-MP/48, delivered in December 1986, should by now be running its first user jobs.

In addition the Computer Board has set aside £5 million to be spent over three years on enhancements to networking facilities, and reviews are being made within the Computer Board and SERC of the need for and possibility of providing distributed facilities.

The Cray X-MP/48 supercomputer

The Cray X-MP/48 is one of the most powerful computers it is possible to obtain. In principle it is capable of performing about a thousand million arithmetic operations per second. In practice it is unlikely to attain this extraordinary level of performance because it would mean making every individual section of the computer perform simultaneously flat out, and although programs can be written to do this they tend to have little relationship to real life applications. Nevertheless, by careful tuning and optimisation of existing scientific programs it is possible to attain a substantial fraction of this theoretical performance for real problems and this is very considerably more than can be obtained from conventional mainframe computers.

The computer achieves its high performance in three main ways. First, it is constructed from very fast components and all possible steps have been taken in its design to reduce the transit time for electrical signals to move from one point to another. The computer is therefore very compact — it occupies only six square metres of floor space. Its compactness leads to formidable cooling problems and the machine is cooled by Freon refrigerant rather than by the air or water used by more conventional computers.

Secondly, the machine contains special hardware designed to handle vectors (strings of numbers) in much the same way as a conventional computer handles individual numbers. This can provide large gains in performance when dealing with repetitive operations on arrays of numbers, as for example in doing the kind of matrix algebra which features prominently in solving sets of equations.

Thirdly, the machine contains many functional units which can operate simultaneously, and clearly, the more one can exploit this parallelism, the greater the overall performance that can be delivered.

Large-scale parallelism

The above features apply to any Cray computer. The X-MP/48 model contains a further element of large-scale parallelism in that it consists effectively of four complete Cray computers (processors) in one box. It is possible to run the four processors almost as four independent machines or, by adding extra instructions to users' programs, one can make all four processors cooperate on a single job.

The X-MP/48 has 8 million 64-bit words of memory and a 32 million word solid state device (SSD) to be used for data files which are required frequently by user programs. Use of the SSD can make it feasible to perform certain types of calculations which might otherwise be impractical if one had access only to traditional, and much slower, disk drives for such data storage.

The Cray also has its own conventional disk drive units and it will have access to other facilities which are now available on the IBM mainframe computing facility at RAL. This IBM system will act as a 'front end' to the Cray. It will provide the route into the Cray from JANET; it will be the machine on which much of the preparatory work is done by users before they submit their jobs to the Cray; and it will provide large-scale storage facilities for long-term data storage. In time, further front-end machines providing somewhat different facilities may be added as funds become available.

Dr B W Davies
Director of Computing, SERC

*The report, *Future facilities for advanced research computing*, is out of print. Copies may be borrowed from public, university or other institution libraries.

The British National Space Centre

Recent issues of the *SERC Bulletin* have reported on the setting up of the British National Space Centre (BNSC) under the leadership of its Director General, Mr Roy Gibson (Volume 3 No 5) and the changes of committee and board structure in the area of the Astronomy, Space and Radio Board's former responsibilities which accompany this new development (Volume 3 No 6). The BNSC has been brought into being, not for any reason specifically related to the needs of space science (ie astronomy and solar system science), but as a result of the Government's desire to give a sharper focus to a wide range of space activities. These include current and future commercial activities, the civil utilisation of space, microgravity and the whole field of Earth observations, as well as space science. Thus the BNSC will be supporting a wide spectrum of users, among whom space scientists will be only one group albeit a highly successful and visible one. How are they likely to fare, in this new different environment, asks Professor Peter Willmore, Chairman of the BNSC's Space Science Programme Board.

Consistent with its role in bringing together these diverse interests in space, the BNSC has produced and submitted to Government a Space Plan of which SERC's plan for space science is an integral part. However it is clear that the administrative upheaval involved will have been of no value at least to space science, and probably also to no one else, if all that now happens is that the funds which have been provided by SERC are simply channelled into the same programme as that which would have been carried out through SERC anyway. If the BNSC is to be judged a success, it will be because it has enabled more or better science to be carried out.

This might come about in a number of ways — for example, space scientists might join with other space users in creating projects which would not be feasible or would cost more without such a collaboration. This is most likely to happen within the domestic space programme; it is unlikely within the European Space Agency programme (the major segment of the whole UK space science activity) because of the way in which it is structured. I believe we must look very hard within the domestic programme for opportunities for gain to space science.

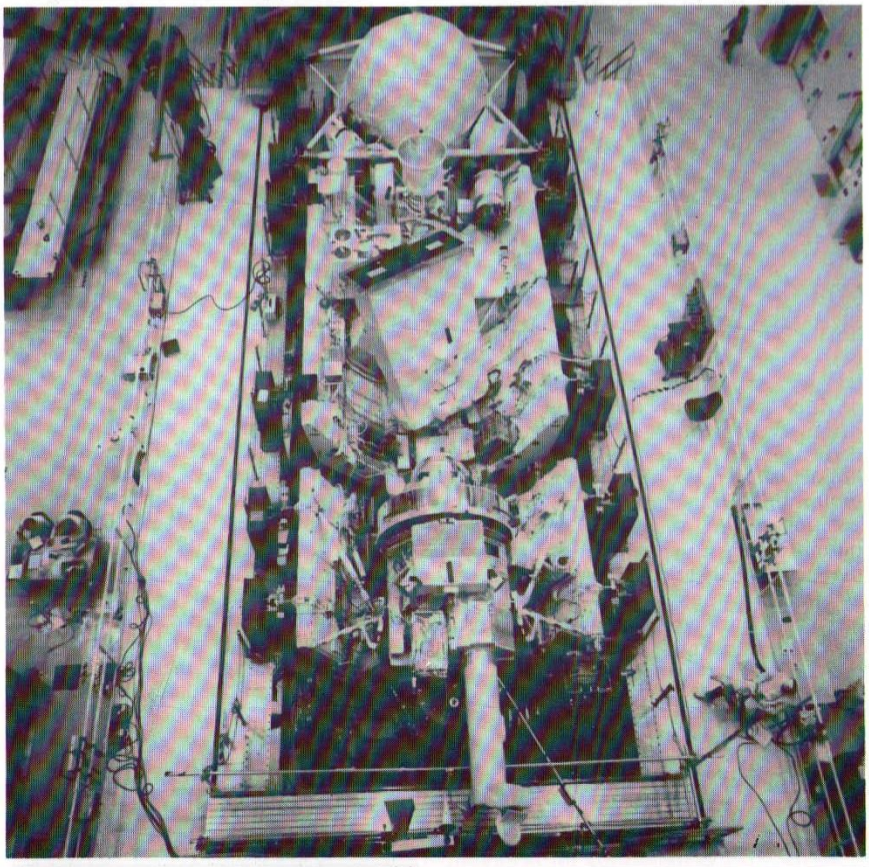
The domestic space science programme has diminished dramatically under the various pressures of the last 10 to 15 years. So has the domestic space programme generally, to the point where this is now recognised as a major point of national weakness. The best features of the Ariel series of spacecraft, which led to the spectacularly successful Ariel V X-ray astronomy satellite launched in 1974, resulted from a collaboration between space science and space technology which neither party could have afforded to maintain subsequently. An expanded programme of domestic space activities would allow this collaboration to be re-established, and perhaps extended, to the benefit of space generally within the UK.

Would such a development be consistent with the recommendations of the Richmond report to the SERC in 1984, which recommended that priority in space science be given to operation through ESA? Certainly, for it is widely recognised that effective participation in such international organisations depends on a minimum healthy level of domestic activity. The ESA mandatory science programme will remain the dominant component of UK space science. It is based on a programme called Horizon 2000, which UK space scientists generally regard as an exciting plan for the next two decades, and one in which they are determined to play as full and active a part as possible.

Here too there is a problem. The Horizon 2000 programme is based on an increased subscription to ESA which is not yet fully agreed, and additional funds will be required before the UK can become fully committed to this programme.

Clearly the BNSC is faced both by an exciting opportunity and by significant problems. We can all hope it will be successful in overcoming them.

Professor A P Willmore
Department of Space Research
Birmingham University



The payload of the Spacelab 2 mission during its integration at Kennedy Space Center before installation in the Shuttle, in which it was launched in 1985. Among the 12 instruments aboard were two major UK telescopes; however, the UK's share of the costs of this $300 million project was only about 1% of the total. The UK has maintained a significant domestic space science programme only by exceptional success in participating in collaborations on advantageous terms.

Observing with FLAIR

The use of low-loss optical fibres has led to a new area of work for the UK Schmidt Telescope (UKST) in Australia. This unique wide-field multi-object spectroscopy system for astronomy has been developed by the Royal Observatory, Edinburgh, and Durham University. The system is outlined here by Fred Watson, who is based at the UKST.

Despite the spectacular advances that have recently opened up the sky to astronomical observation over a wide range of wavelengths, optical spectroscopy remains a cornerstone of contemporary astrophysics. So great is the information content of the optical spectrum of a celestial object that it is almost always a necessary observation to secure. But, because much of today's astronomy is concerned with the study of large numbers of objects, there is real difficulty in gathering the data when traditional 'one-at-a-time' methods are used.

Optical fibres for reformatting

With these considerations in mind, a number of observatories have recently experimented with simultaneous multi-object observational techniques. One of the most successful of these involves the use of low-loss optical fibres, originally developed for the communications industry. The fibres are used in bundles of perhaps 50 (one fibre for each target object in the field of view) and their input ends are mechanically aligned with the required images in the focal surface of the telescope. At the other end, a few metres away, the fibres are arranged in a straight line along the slit of a spectrograph. The fibre bundle is acting as a reformatting device, changing the random distribution of target objects in the field to a linear array of points. The end product at the detector is a neat stack of spectra of the target objects. It is apparent that, for such a multi-object technique, the field of view of the telescope concerned becomes comparable in importance with its aperture.

Wide field possibilities and problems

The UK Schmidt Telescope in Australia, normally used for taking very detailed wide-angle photographs of the sky, has a field of view six and a half degrees on a side, some 40 times that of a conventional reflecting telescope. Thus, although the UKST's moderate aperture of 1.2 metre collects only one tenth of the light gathered by, say, a telescope of 4 metre aperture, its wide field enables it to obtain multiple spectra much more efficiently than a 4 metre telescope when the objects are moderately bright (above about 18th magnitude) and distributed on the sky of the order of one per square degree. Such objects include galaxies, bright quasars and numerous types of stars..

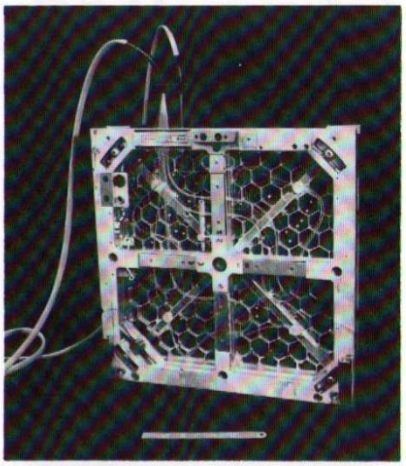
There are several practical difficulties associated with this. For example, the focal surface is steeply curved and is buried deep within the telescope tube. Differential atmospheric refraction across the wide field of the telescope is sufficiently large to become a problem for very long integration times. Most serious, however, is the very small size of the images produced by the telescope, so that the fibres must be positioned with an accuracy of a few microns to intercept the light from the target objects. Fibre positioning methods currently used on larger telescopes are not sufficiently accurate.

The FLAIR system

A system has now been developed which overcomes these difficulties. Known as FLAIR (Fibre-Linked Array-Image Reformatter), the system uses 40 fibres of 40 microns core diameter (corresponding to 2.7 arc seconds on the sky) which can be positioned in a special plateholder in alignment with selected target objects spread over the 40 square-degree field of the telescope. The required precision is achieved by a novel optical positioning method, in which the input ends of the fibres are attached directly to the images on a specially-prepared thin glass positive copy plate of the target field, using a rapid ultraviolet-curing optical cement. (This task is equivalent to sticking a pin in an area the size of two tennis courts with a positional accuracy of half a millimetre!). When observations of a particular set of target objects are completed, the fibres can be released from the plate and used again.

At its output end, the fibre bundle feeds a small spectrograph built specially for the purpose. Since optical losses within the fibres are relatively small, the fibre bundle can be made long enough to mount the spectrograph in a stationary position on the observing floor, permitting the use of a simple and inexpensive design which nevertheless has very high stability.

During the initial test period, the spectra were detected using hypersensitised spectroscopic film in an ordinary 35 mm camera body, and useful data were obtained on several classes of star brighter than 16th magnitude. A more sensitive cryogenic camera system using a charge-coupled device (CCD) has now been built for FLAIR by Durham University with the initial aim of carrying out a galaxy redshift survey.



Back view of the FLAIR plateholder, showing fibres positioned in alignment with 40 target objects. The honeycomb structure deforms the plate carrying the fibres to match the focal curvature, while allowing the fibres themselves to pass through.

In order that the real image formed in the telescope can be registered with the copy plate carrying the fibres (again to an accuracy of about 10 microns), FLAIR includes ancillary fibres and an acquisition image-guide, used to observe six fiducial stars with a low light-level TV camera. The alignment is facilitated by the use of a plate-rotation mechanism in conjunction with the computer-controlled guide-star offset system on the telescope's autoguider. FLAIR has been designed to dovetail with the normal photographic operation of the telescope so that the two modes can be rapidly interchanged, making the best use of the prevailing sky conditions.

Work is now in progress on more fibre feed bundles, a second fibre plateholder, and a new fibre-positioning table, with a view to beginning a user-oriented spectroscopy service in 1987.

FLAIR is currently the only wide-field multi-object spectroscopy system operating anywhere in the world. It is also unique among astronomical fibre-optics systems in combining a multi-object capability with an off-telescope spectrograph. It represents a new, effective and inexpensive way of exploiting simultaneously the extraordinarily wide field of the UK Schmidt Telescope and the sensitivity and linearity of modern two-dimensional electronic detectors.

Fred Watson
Royal Observatory, Edinburgh

Infrared studies of the Galactic Centre

An international group of scientists, using SERC's 2.5m Isaac Newton Telescope on La Palma in the Canary Islands, took advantage of a rare astronomical event in the autumn of 1986 to probe the mysteries of the centre of our Galaxy.

About every 19 years, as the Moon orbits the Earth it makes a few passes over the centre of our Galaxy. On 11 September 1986, the first of a series of three of these events occurred: the dark limb or edge of the Moon occulted the part of the sky where the centre of our Galaxy lies.

The only major observatory where the occultation was visible was on La Palma, where an international team of astronomers from Leicester University, the Royal Observatory, Edinburgh, Hawaii University, Stockholm Observatory and the Anglo Dutch partnership on La Palma, and backed by staff from the Royal Greenwich Observatory, was ready and waiting for the crucial moment.

The Galactic Centre cannot be seen in visible light because foreground dust clouds in the Galaxy block the view. Infrared and radio radiation can however penetrate the dust, and it is from studies at these wavelengths that knowledge of the centre is drawn. First identified by radio astronomers and placed 30,000 light years from us, the Galactic Centre is believed to be a black hole surrounded by an accretion disk of gas, which it consumes. Infrared maps of the same part of the sky show a complicated set of muddled objects, called IRS-16, one of which was believed to be identified with the Galactic Centre. The aim of the observations was to use the Moon as a shutter to analyse the images, sort out the confusion and identify the black hole.

Using infrared equipment constructed at Leicester University, mounted on the Isaac Newton Telescope, the team observed the signal as the Moon's limb took 20 seconds to cut across the central 6.5 arcsecond region of the Galactic Centre. From the 1000 measurements taken in the vital 20 seconds, it is already apparent that IRS-16 has at least five separate components. The Moon took a distinct time to pass in front of, and extinguish, the infrared radiation from one of these: it is likely to be a star cluster, in the line of sight to the Galactic Centre.

The other four sources were cut off more rapidly, two of them so sharply that they must have dimensions smaller than our Solar System. In the preliminary analysis performed so far it appears that one of these two sources is coincident with the radio source which lies at the Galactic Centre.

This one is the candidate for the central black hole in the Galaxy. Whether or not this identification stands up to further analysis and observation, it is already clear that any black hole in the centre of our Galaxy is very much less luminous than any seen in external galaxies.

The object of a lunar occultation observation is to obtain a clearer picture of the region, as ground-based astronomical pictures are normally blurred by atmospheric turbulence.

Two further night-time occultations of the Galactic Centre in this series can be observed during 1987 from Hawaii, weather permitting. After that it will be necessary to wait 19 years for more attempts.

UK-built X-ray detector to fly on Japanese spacecraft

A team from Leicester University and Rutherford Appleton Laboratory (RAL) delivered a large X-ray detector to Japan in October 1986. It is for the Astro-C satellite now being tested at the Japanese Institute of Space and Astronautical Science (ISAS) in Tokyo. The launch is scheduled for February 1987 on the new Japanese Mu 352 rocket. Astro-C will be of crucial importance to astronomers over the next few years because of its sensitivity and the likelihood that no other non-Soviet X-ray missions will fly before 1990.

Astro-C carries three experiments. Leicester University, RAL and ISAS are providing the Large Area Counter, consisting of eight detectors with an area of some 5000 cm^2; this will study the variability in cosmic X-ray sources over time periods ranging from a fraction of a second to a number of months. An All-Sky Monitor built by the University of Osaka will search for short bursts of X-rays from weak sources as well as dramatic changes in more powerful sources; and a Gamma-Ray Burst detector from Los Alamos in the United States will monitor the sky for isolated flashes of gamma rays.

Astro-C will concentrate on observing the variation of X- and gamma-ray sources such as neutron stars or 'black holes', in order to understand the physical processes involved in high-energy emission.

The project was supported initially by SERC but now comes under the aegis of the British National Space Centre (BNSC). Mr Jack Leeming, BNSC's Director of Policy and Programmes, expects to attend the launch with Professor Ken Pounds of Leicester University, who leads the project in the UK.

High altitude research stations, Switzerland

The International Foundation for the High Alpine Research Stations at Jungfraujoch and Gornergrat in Switzerland is supported by contributions from several European countries, including the UK whose annual subscription is paid by the Royal Society. The aim of the Foundation is to make possible scientific investigations which must be carried out at high altitude or in a high alpine climate. The research station and Sphinx observatory at the Jungfraujoch, together with the two astronomical observatories, Gornergrat South and Gornergrat North, are run for this purpose. Scientists from universities, institutes of technology and other research institutes of the member countries can carry out time-limited research experiments in these buildings.

The Jungfraujoch and Gornergrat scientific stations both lie far from large cities and industrial centres. With a prevalent atmospheric pressure of 655 mb, the Jungfraujoch scientific station lies above the lower third of the Earth's atmosphere, where about 95% of the aerosols are suspended. The site is very favourable for all types of research which require a high atmospheric transparency over a wide spectral range and the absence of local sources of pollution. The Gornergrat site has the same advantages as the Jungfraujoch and it is at present dedicated to observational astronomy. Both stations are accessible all the year round by narrow gauge railways capable of transporting heavy equipment.

A full description of the Research Stations can be obtained from Mr P Cass, Astronomy and Planetary Science Division, SERC Central Office, Swindon, ext 2266.

X-ray laser breakthrough at RAL

Experiments carried out last summer at the Central Laser Facility (CLF) at Rutherford Appleton Laboratory by a consortium of UK researchers have demonstrated laser amplification at a wavelength of 8 nanometres. This exciting result puts the UK scientists ahead of the world in the quest to develop lasers at the shortest possible wavelengths. The consortium included groups from Queen's University of Belfast, Hull University, Imperial College of Science and Technology and RAL, writes Dr Mike Key.

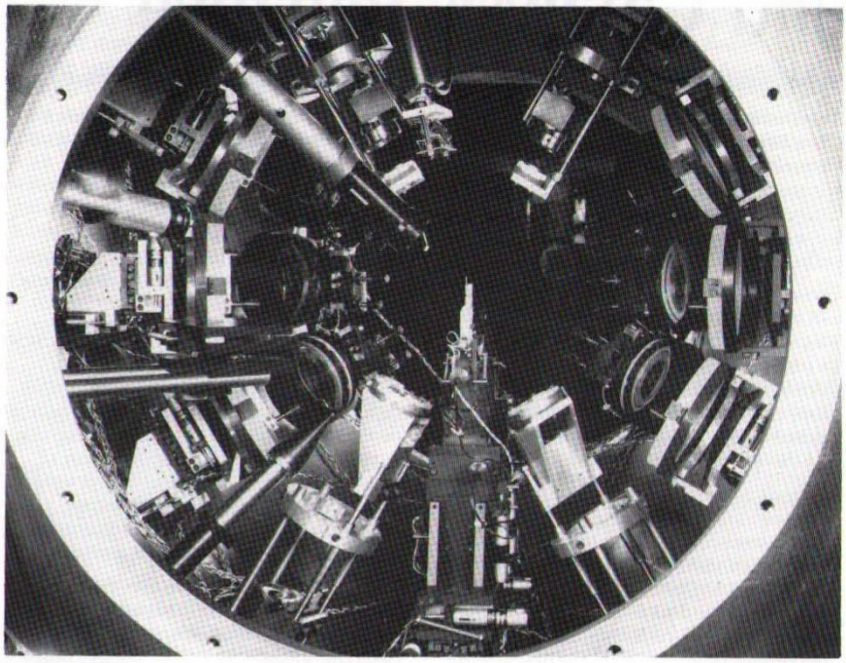
The goal is to reach wavelengths in the 'water window' below 4 nanometres where the X-rays can penetrate water are absorbed strongly by carbon-based materials such as proteins. This could open the door to the future possibility of three-dimensional holographic study of the structure of living cells.

A surge of interest in XUV lasers came in 1984 when experiments with the largest laser in the world (the Nova facility in the USA) demonstrated strong laser amplification at 21 nanometres. Work at the CLF was held up at that time by budget cuts caused by the fall in the value of sterling, and construction of a highly novel system for XUV laser research was delayed until the summer of 1985. The new system, using off-axis reflection from spherical mirrors to produce an aberration-free line focus, was an immediate success. Its first use demonstrated 50-fold laser amplification at 18 nanometres. The experiments used the unique optical design to irradiate up to 2 cm lengths of 7 μm diameter carbon fibres with the full six-beam power of the Vulcan neodymium glass laser facility.

The capability to irradiate such a small cylindrical target makes it possible to use a different laser concept from that developed in the USA, and moreover one which is more easily scaled to shorter wavelengths. As a result, the UK groups were able to design an experiment using a 7 mm by 7 μm diameter fibre target coated with lithium fluoride to produce laser action at 8 nm, the shortest wavelength in the world to date.

The mechanism of the laser

The thin cylindrical target is intensely heated by the focused power of the laser and, during the extremely short pulse (70 picoseconds), a surface layer just a few hundred nanometres thick is raised to a temperature of several million degrees. The atoms become fully ionised to form a plasma of bare nuclei (F^{9+}) and free electrons. The hot plasma layer has enormous internal pressure (more than 10 million atmospheres) and explodes away from the cylindrical core.



View inside the target chamber showing the target mount at the centre and the arrangement of lenses and mirrors to produce a line focus.

As it expands, it cools adiabatically and in about a nanosecond its temperature drops as much as ten-fold. At the lower temperature, electrons recombine rapidly with the bare nuclei but tend to fill the higher energy orbits of the hydrogen-like F^{8+} ions.

Measuring the laser amplification is difficult since it lasts for less than 10^{-9}s and is confined to within 0.2 mm of the fibre target. Two novel time-resolving spectrometers based on variable periodicity grazing-incidence diffraction gratings were developed to record the emission spectra along the axis and transverse to the fibre.

The axial-to-transverse intensity ratio indicated ten-fold amplification in a length of 7 mm. That is as much length as Vulcan is capable of heating adequately for the fluorine laser. More amplification and shorter wavelength need more laser power and improved efficiency in the X-ray laser design. Both are possible and a wavelength of 8 nm is tantalisingly close to the ultimate goal of the water window.

M H Key
Rutherford Appleton Laboratory

Exploration of space

Exploration of space is an exciting new gallery at the Science Museum which charts the progress of spaceflight from the ancient Chinese gunpowder rockets to proposed projects for manned space stations. Organised into eight main sections which focus on subjects as diverse as 'How rockets work' and 'Robot explorers', the gallery is destined to be one of the highlights of the museum.

The bulk of the gallery is made up of rockets and satellites from the museum's own collection — but there is also a lot of new material gleaned from the big names in the space business. Rutherford Appleton Laboratory has supplied some of the hardware on display and several photographs, including an engineering mock-up of the AMPTE satellite and a scale model of IRAS. Satellite instruments and examples of experimental equipment made at RAL are also on show.

The Science Museum is open Mondays-Saturdays 10:00 - 18:00 and Sundays 14:30 - 18:00.

Formation of Interfaces and Catalysis Initiative

The Council is sponsoring through its Chemistry and Process Engineering Committees an intiative to link surface science with the study of heterogeneous catalysis and to encourage the use of new techniques to study catalysis under realistic conditions.

The expected budget of the programme will be about £6 million over six years. This will largely support research grants to academic institutions, including Cooperative Research Grants, but a proportion will be used to support studentships earmarked to the initiative and the provision of central facilities.

A major objective is to bring together the communities of researchers in surface science and in heterogeneous catalysis, to involve the process engineering community where appropriate, and to foster industrial collaboration. A coordinator will act as the contact point for universities, polytechnics, companies and other organisations wishing to become involved in the programme, and will arrange meetings of various groups for scientific discussion.

The need for research in interfaces and catalysis

Recent exciting developments in the field of surface science make the formation of an initiative in the area of interfaces and heterogeneous catalysis particularly timely. With these developments has come the need to draw surface scientists into considerations of the problems of catalysis, and to build bridges between the communities researching in surface science and catalysis.

Catalysis plays a vital role in the British economy, but there are two factors which, if uncorrected, will significantly reduce our competitiveness in this sector of the chemical industry. These are the current shortage in the production of suitably qualified PhD-trained people; and the shortage of technological developments from which commercially exploitable applications can emerge.

The aims of the initiative are, broadly, to maintain, develop and expand UK expertise in surface science, and in catalytic science and technology; and to bring together the surface science, catalytic science and process engineering communities in a modern and innovative approach to the development of our understanding of fundamental catalytic processes and, ultimately, to catalyst design and development from scientific principles.

Industrial catalysts are complex systems; one role of surface science is to develop, experimentally and theoretically, our knowledge of the properties and behaviour of simpler, well defined systems. Moreover, recent advances in the understanding of the behaviour of real catalysts provide indicators of areas into which surface science could profitably develop. Certain of these rapidly advancing areas in catalysis require to be strengthened and consolidated, particularly with input from surface scientists and from process engineers.

The participation of industry in this initiative is seen as vital, and the links between the academic and industrial communities are therefore seen to be an important element of the initiative.

Aims of the initiative

1. To direct the attention of surface scientists towards problems in heterogeneous catalysis, enabling relevant work to be carried out at a fundamental level; and to develop and use appropriate techniques for *in situ* analysis of model systems at high pressures.

2. To encourage the development of correlated studies of single crystal surfaces and high area catalysts; and to extend the scope of surface science to include the study of appropriate non-metallic materials.

3. To develop new pathways for the design and synthesis of new catalysts, in particular drawing on fundamental developments in surface science for design criteria and in materials science technologies (for example, metal/semiconductor systems, molecular beam epitaxy, ion plating, etc) for the production of novel surfaces of catalytic significance.

4. To examine the role of promoters, poisons, surface carbon, and structural factors in catalytic activity and selectivity.

5. To encourage *in situ* examination of catalysts under operating conditions by techniques such as infrared, X-ray, neutron and Raman methods, and the characterisation of the dynamic state of catalysts under working conditions.

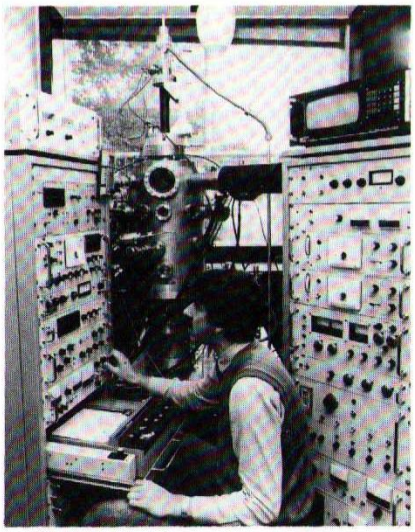
6. To encourage the development of new high-area catalysts, satisfying the demands of process engineers, with well defined phases, or supports, or both (for example, oriented supported metals; supported metal clusters; or metal ensembles of known structure); and to study industrial catalysts as multicomponent systems.

7. To encourage the development of new catalyst systems for established processes, and the development of new applications for surface science and catalyst technology.

For further information on the initiative, contact Mr Ron Coster, SERC Central Office, Swindon, ext 2263.

Examples of research areas expected to feature in the initiative

- *fundamental work on reactant activation, for example alkanes and nitrogen*
- *direct hydrogenation of carbon monoxide to oxygenated compounds such as ethanol*
- *more imaginative use of oxide supports for metals and for the creation of novel dual function catalysts*
- *development of oriented supported metal catalysts, ordered alloys or metal/semiconductor sandwich structures, and 'strained-metal' catalysts*
- *efficient asymmetric hydrogenation for the production of optically active chemicals relevant to the pharmaceutical and agrochemical industries*
- *preparation of naked metal clusters by use of ultrasonic beams*



High-resolution electron energy-loss spectroscopy instrumentation for studying surface vibrations, at Liverpool University

Morphology of electromagnetic fields

A novel experimental technique has been developed in the Physics Department of Bristol University for making precise measurements, point by point, in microwave fields. The technique provides full quantitative information about the amplitude, polarisation and phase of both the electric and magnetic fields at each point in space. This is done by using movable probes that act as modulated scatterers. The probes cause negligible disturbance to the fields because there are no metallic connections to them. Professor John Nye, joint winner with Dr J V Hajnal of the National Physical Laboratory's Metrology Award, describes how the technique has been used to test new ideas about the structure of electromagnetic fields.

Field problems that are amenable to analysis nearly always possess some symmetry. To come to grips with complicated fields that are completely lacking in symmetry it is useful to start by identifying their singularities — just as, for example, a two-dimensional pressure field might be characterised in the first instance by the positions of its highs and lows and saddles. To adopt this point of view for optical and microwave fields we must ask: are there features of such fields that are *generic*, that is, features that will occur naturally, without special conditions, in all fields of sufficient complexity? Such features will necessarily be stable against perturbation ('structurally stable').

In optical wave fields the interference fringe is a feature of this kind. As usually conceived, it is a singularity in a (complex) scalar field: in three dimensions, a line where the wave amplitude is zero. The true situation must be more complicated than this because of the vector nature of the electromagnetic wave, and indeed the Bristol work has shown that interference fringes possess a characteristic fine structure.

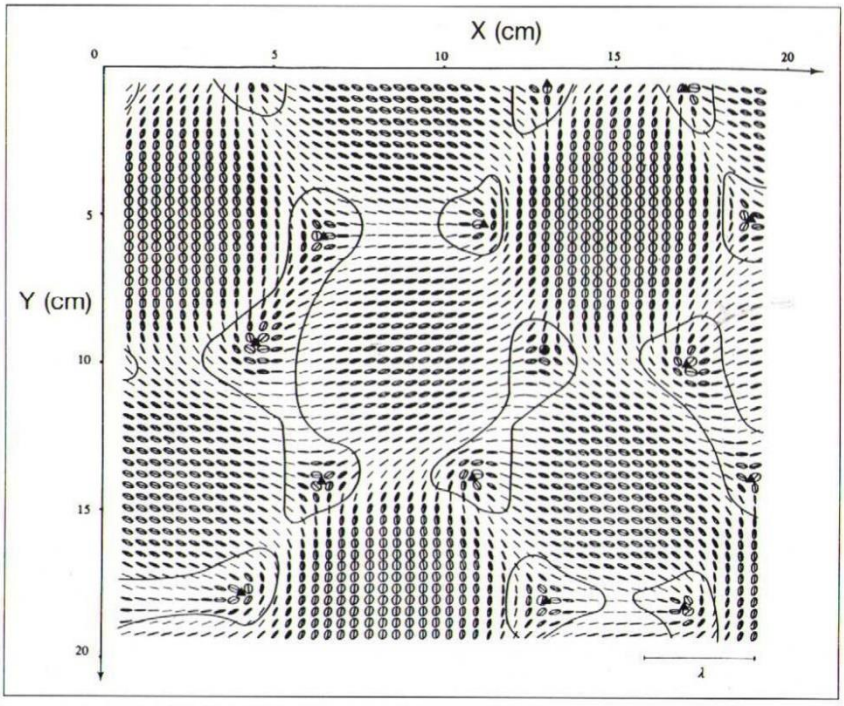
The polarisation of the wave must be considered, and in general propagating wave fields it will be non-uniform. Theory predicts that the salient structurally stable features are the lines, in three dimensions, where the wave field is circularly polarised, and the surface where it is linearly polarised. This has now been verified in experiments by J V Hajnal (see figure) with 3.5 cm microwaves (8.5 GHz) which measure the amplitude, polarisation and phase of an electric wave field point by point. The system uses a development of the well known modulated scatterer technique. Its essential element is a field probe with no wires connected to it that could disturb the field being measured. The probe consists of two small dipoles loaded at their centres with phototransistors and bonded together in the form of a cross. Audio-frequency optical signals, conveyed along optic fibres, illuminate the phototransistors and thereby modulate the scattering cross-sections of the dipoles. The scattered waves are picked up by a receiver placed outside the main beam; they contain the required information about the field and may readily be distinguished from the background by their modulation.

The transverse section of a wavefield in the figure shows several points of circular polarisation and each is surrounded, as expected, by one of two, topologically possible, patterns of polarisation ellipses. These singular points organise and underpin the whole pattern. The figure also shows lines where the polarisation is linear, which divide the field into left and right-hand regions. By using loop scatterers in place of dipoles, similar measurements have been made of the associated magnetic wave field.

The connection with interference fringes can be made by noting that a general field can be resolved into left and right-hand circular components, the zeros (interference fringes) of the left-hand field being right-hand C lines (lines of circular polarisation) and vice versa. An interference fringe in a linearly polarised field, to take one example, would consist of a right and a left-hand C line exactly superposed, but this arrangement is structurally unstable. In any real situation, close inspection would show the fringe to be split into a separated pair of structurally-stable C lines.

So far the probes have only been tried in free-field conditions. Experiments now planned at the National Physical Laboratory will extend the measurements to open transmission cells and to the near fields of antennas.

Professor J F Nye
H H Wills Physics Laboratory
Bristol University



Map of the measured polarisation ellipses for the transverse electric field in a cross-section of a 3.5 cm microwave field. Amplitude information is not represented. Triangles mark points of circular polarisation, where the orientation of the polarisation ellipse is singular. Two types occur, distinguished by different local patterns of polarisation ellipse, and in this example all are right-handed. The solid lines are contours of linear polarisation, delineating islands of right-hand polarisation in a sea of left-hand polarisation.

Stochastic dynamics of nonlinear systems

Research by the Lancaster/UMSL (University of Missouri, St Louis) nonlinear dynamics group is enhancing our understanding of the diverse and often unexpected ways in which nonlinear dynamical systems are affected by noise. The work is of wide-ranging significance, with applications throughout physics, chemistry, biology, engineering and other branches of science and technology. It is described here by Dr Peter McClintock and Professor Frank Moss.

Nature is inherently both nonlinear and noisy. It is nonlinear in the sense that the restoring force on a system displaced from equilibrium is not, in general, linearly proportional to the size of the displacement (though it may seem to be so if the displacement is small enough, as in the familiar case of the simple pendulum). It is noisy in the sense that every macroscopic natural system is subject to fluctuations. These may be internally generated, an effect that generally increases in importance as the physical scale of the system decreases, or they may be externally generated corresponding, for example, to fluctuations of the environment in which the system is placed. Such fluctuations may come relatively slowly, as for example the variations of light intensity and temperature (on a scale of hours) to which biological systems are often subject; or they can be exceedingly rapid, an example being the quantum noise (on a scale of picoseconds) generated within the optical cavity of a laser. What is common to these seemingly very different situations is that the fluctuations can exert a potent influence on the behaviour of the system in question, often doing so in quite unexpected ways.

Nonlinear sytems

The properties of nonlinear systems are, in general, rather hard to calculate, even if the possible influence of fluctuations is ignored. The traditional approach has been to linearise the relevant differential equations, forget about the presence of the noise, and then seek solutions that are applicable within a noise-free small-amplitude linear regime. Approximate methods, such as perturbation theory, are then used in an attempt to extend the treatment to cover behaviour under more general conditions. The trouble with this latter procedure is that it does not always work. By ignoring the influence of noise and by throwing away small and seemingly unimportant higher order terms, it is all too easy to throw out the baby with the bathwater in that one has at the same time, inadvertently discarded all information about some of the system's most interesting and striking properties. This particular danger, fortunately, has now become widely recognised as a 'booby trap' for the unwary, to be most carefully avoided.

Current work on nonlinear dynamical systems can be divided into two broad areas. Both of these are of high current interest and each of them is developing with quite bewildering speed. First, there are deterministic systems, in which any fluctuations or driving forces are cyclical in character and where, at least in principle, it is possible to predict the state of the system at all future times from a knowledge of the starting conditions. It is systems of this kind that exhibit the celebrated routes to deterministic chaotic behaviour via, for example, a cascade of period-doubling bifurcations as a control parameter is being varied. Work in this area is the subject of a special initiative by the Mathematics Committee of SERC (see *SERC Bulletin* Volume 3, No 5, Summer 1986).

The second major area of nonlinear research treats nondeterministic systems, where random fluctuations are imposed, as is so often the case in nature, and it is the subject of the present article. Work in this latter area is being supported by SERC's Physics Committee and by NATO.

Noisy differential equations

It is a remarkable fact that highly complicated nondeterministic systems can often be described in terms of relatively simple-looking differential equations. Despite their innocuous appearance, however, the solution of stochastic (noisy) equations of this kind is, in general, extremely difficult. Solutions must of course be sought, not in terms of discrete values but, rather, in terms of statistical quantities such as probability density functions, correlation times, power spectra or first passage times. There are three main approaches to the problem, each of which has its own particular advantages and disadvantages.

1. Analytic or semi-analytic solutions may be derived. With the exception of a few special cases, however, approximations are required and these naturally introduce an element of uncertainty about the range of validity of the answers obtained. It is an unfortunate, albeit ubiquitous, characteristic of nonlinear systems that approximations introduced at one point in the analysis, and quite valid at that point, may become extremely poor

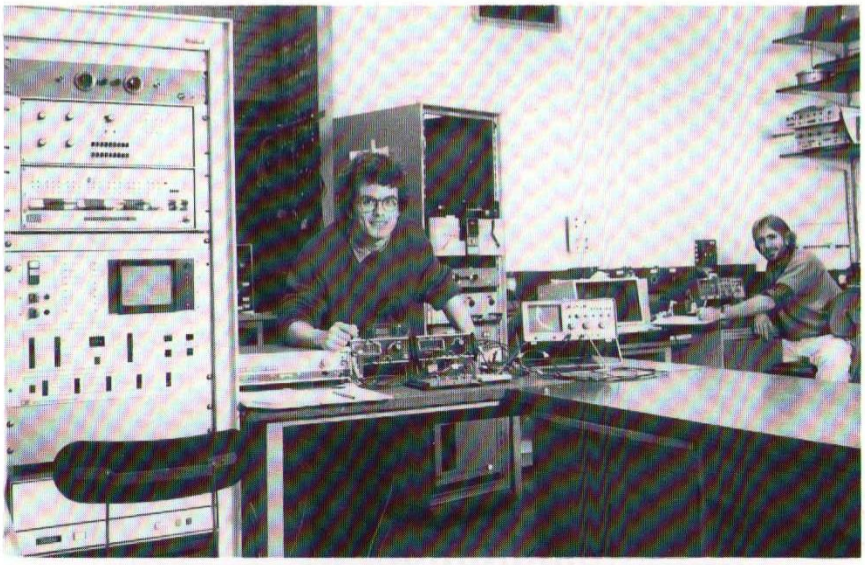


Figure 1: Analogue experiments in progress at Lancaster University. Dr Riccardo Mannella (left) is studying Hopf bifurcations in a Brusselator; Mark James (right) is developing techniques for modelling stochastic nonlinear systems with periodic potentials. (Photo: Lancaster University).

approximations close to the parameter space.

2. Digital simulation can be used. The results can be of high accuracy assuming, of course, that the appropriate algorithm has been correctly programmed. However, particularly for multivariate systems, huge amounts of computer time may be required to achieve reasonable statistical quality.

3. Analogue experiments can be performed on electronic circuits (figure 1). Although this approach is inherently less accurate than digital simulation, the experiments are relatively quick and straightforward, and they yield results of excellent statistical quality. Furthermore, in subtle ways, they model natural systems much more faithfully than can ever be the case with a digital simulation.

These three quite different approaches are mutually complementary. They have been described as forming a tripod. If all yield the same result, that result can be accepted with a high degree of confidence. If, on the other hand, one of them gives a significantly different answer from the other two, then the tripod falls because one leg is the wrong length; further work is then required to establish the truth.

Nonlinear dynamics group

The Lancaster/UMSL nonlinear dynamics group is devoted to the solution of topical problems in stochastic dynamics, particularly through the application of analogue methods, but also through the use of digital simulation wherever appropriate. The research programme is innately international in character. It is being carried forward in collaboration with stochastic theorists in several countries, as indicated in figure 2. Problems recently or currently under investigation include:

- In collaboration with the Institute of Semiconductors, Kiev: studies of the power spectral density of the under-damped double-well Duffing oscillator driven by a random force (figure 3);
- With the Prigogine Center, University of Texas at Austin: investigations of noise-induced phase-transitions; also, studies on a proposed mechanism for molecular chiral selection by parity-violating, weak neutral-current interactions during the era of pre-biotic evolution;
- With the Polytechnic Institute of New York: investigation of the stationary, joint statistical densities of velocity and displacement (stochastic phase portraits) in three dimensional systems (figure 4);
- With the University of Ulm and, later, the Max Planck Institute for Quantum Optics in Munich: studies of the stochastic dynamics of a variety of nonlinear systems with periodic potentials; work that is relevant to the understanding of charge density waves and the ring laser gyroscope;
- With the University of Pisa: studies of relaxation and probability density for bistable devices driven by coloured noise;
- With the Free University of Brussels, and with the University of Pisa: stochastic postponements of noisy Hopf bifurcations, with applications to nonequilibrium, oscillating chemical dynamics;
- With the University of Barcelona: studies of the correlation times of nonlinear systems and of the critical slowing down that occurs near an instability.
- With colleagues at Lancaster University (Dr C J Lambert and his condensed matter theoretical group): investigations of modulation-induced negative differential resistance in a class of overdamped nonlinear oscillators.

Future development

Given the speed with which the study of nonlinear dynamics is evolving, it would clearly be imprudent to try to predict the long-term development of the research programme in fine detail. In the near future, however, the group intends: first, to try to gain a deeper understanding of time-evolving stochastic systems; secondly, to investigate the noise-driven diffusion of a particle moving in a random potential; and, thirdly, to study a range of important problems that lie within the exciting interface region separating the two broad areas of nonlinear dynamics mentioned above.

Dr P V E McClintock
Lancaster University
Professor F E Moss
University of Missouri, St Louis

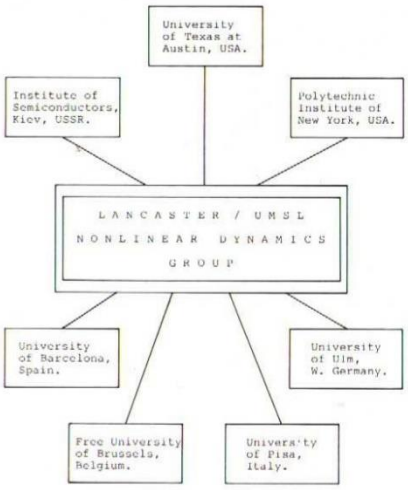


Figure 2: Some SERC-supported Lancaster/UMSL research collaborations in nonlinear stochastic dynamics.

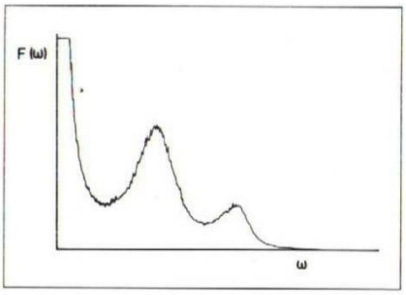


Figure 3: The power spectral density measured for an underdamped double-well Duffing oscillator exposed to a random force. The prediction by the Kiev theoretical group, that there would be a pronounced maximum at zero frequency, was subject to considerable controversy until triumphantly vindicated by the analogue experiment.

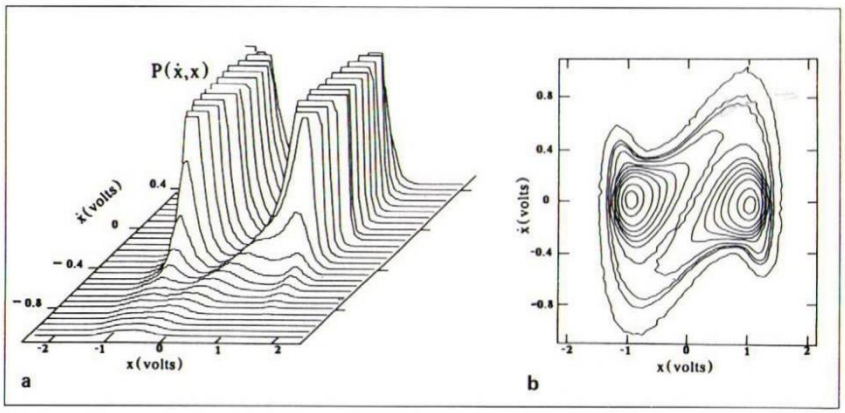
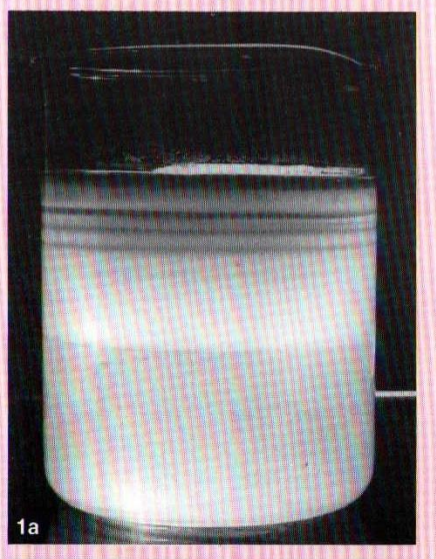


Figure 4: The stochastic phase portrait measured for a damped anharmonic oscillator driven by exponentially correlated Gaussian noise: (a) as a three-dimensional plot; (b) with contours representing loci of constant probability.

Structured laboratory growth models in microbiology

What do the following have in common? A bacterial colony, the fouling of marine surfaces, a freshwater sediment, a soil crumb, a scraping of material from a tooth surface, the film of organisms surrounding a plant root, a polluted fresh water lake in summer...and so on. They are in fact all spatially heterogeneous microbial ecosystems. This means that microorganisms present proliferate in physico-chemical gradients. Some of these gradients are steep, for example in the bacterial colony or in dental plaque, while others, writes Dr Julian Wimpenny of University College, Cardiff, are very shallow as is normally the case in a stratified body of water.

These examples are very clearly different from growth systems used by microbiologists to investigate organisms in the laboratory. Here the commonest tool has been continuous culture in well stirred laboratory fermenter systems. The latter make a virtue out of homogeneity, indeed continuous culture kinetics taught to generations of microbiology students is based on the fact of homogeneity. The question remains: can one predict the emergent properties of microbial communities in structured space using homogeneous laboratory culture systems? We believe that the answer to this question must be no, and it has therefore been the aim of the Cardiff research group to develop a family of laboratory model systems which incorporate spatial heterogeneity. This article describes the progress that has been made so far.



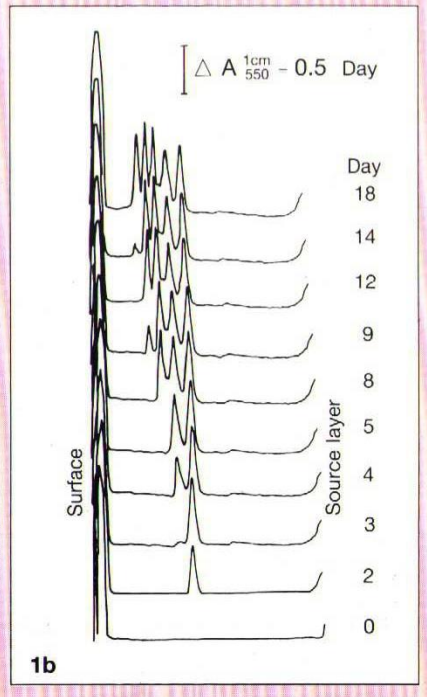


Figure 1: Banded growth in cultures of Bacillus cereus *growing in opposing gradients of glucose and oxygen. a: Photograph of the complete system after six days' incubation at 30°C. b: Scans of each culture after the stated incubation time.*

Gel-stabilised models

The addition of a gelling agent to solutions prevents normal bulk flow due to convective forces, and solute transfer is almost entirely due to molecular diffusion. If the gel contains an inoculum of bacteria and nutrients are available, growth can take place.

We considered this to be an appropriate model to study stratified microbial ecosystems, and R W Lovitt and the author used it to investigate the structure of the community which exists in the bottom water in an oil storage tank. In later experiments, S G Whittaker, J P Coombs and the author investigated the growth of a number of species in oxygen/glucose counter gradients. Interestingly, many of these systems produced periodic growth bands. One organism in particular (*Bacillus cereus*) proved a most prolific band generator (figure 1a) and was investigated further. Band formation required oxygen and glucose counter-gradients and growth position was sensitive to glucose concentration. Band formation occurred sequentially from about the middle of the gel up towards the surface (figure 1b). Large pH changes were noted in the gel system. Surface growth at the expense of amino acids led to the formation of alkaline products and the pH here rose to 7.8-8.0. In contrast, the cells beneath the surface fermented glucose-to-acidic end products so that the pH fell to 5.1. Bands seemed to appear near the junction of the opposing waves of acidity and alkalinity. It was shown that changing the buffer concentration altered both the pH gradients and the position and intensity of the bands. If the gels were incubated anaerobically, the gel became uniformly acidic and band formation was not observed. Finally, addition of a layer of agar containing alkali to the surface of the anaerobically incubated gel led to pH gradients and to band formation.

While it was clear that pH changes were implicated in pattern formation, a physiological explanation was not readily apparent. S Jaffe investigated the system using computer simulations. If the reaction diffusion equations were solved assuming Fickian diffusion and a simple Monod growth kinetic model, the simulation never produced growth bands. Periodic structure could only be produced by invoking an asymmetric activation threshold for growth. This assumed that the cells were either in an active or an inactive state. They could be switched 'on' by a specific environmental factor at one value: they were then switched 'off' at another. The target parameter seemed to be pH value. Two possibilities were investigated; first, that there was hysteresis in the relationship between growth rate and *direction* of pH change; second, that asymmetry was due to a lag in growth initiation but not in its cessation. Experiments designed to test these possibilities favour the second (and more readily acceptable) thesis.

If this example of pattern formation were unique in microbiology, it might not seem worth pursuing such a physiological freak. It transpired however that there were a number of other examples of periodic growth structures reported sporadically through the literature. Indeed, pH may be an important cause of periodicities, but it is certainly not the only one. Examples of pattern formation can be due to other inhibitor effects, for example oxygen gradients to organisms sensitive to it. Have these patterns any ecological significance? The Russian microbiologist Perfilev noted profuse banding of the iron-oxidising species *Gallionella* in marine sediments. It seems possible that many other examples exist but that they

have not been reported because no one has looked for them.

Steady-state gradient models

The gel-stabilised ecosystem has been a useful tool in its own right. It has the disadvantage that it is a closed system, exactly analagous to a batch culture. Our research asked the question, "Is it possible to devise steady-state (open) gradient systems?" R W Lovitt and the author developed a bidirectionally linked multi-stage chemostat which we called the 'gradostat'. This incorporated the ideas of bidirectional exchange first proposed by Margalef in 1967 and incorporated into a simple ecological model by Cooper and Copeland in 1973. The gradostat was recognisably a development of multistage continuous culture systems and its properties were investigated both experimentally and theoretically using a computer simulation written by S Jaffe. The most recent version of the gradostat employs direct coupling between vessels as shown in figure 2. An even simpler version is under development which should allow a greater number of linked growth chambers giving a system which, though still 'open', has higher spatial resolution.

The microbial film fermenter

Another common natural microbial ecosystem is microbial film. The ability of microbes to attach to surfaces exposed to appropriate nutrients and water ensures the ubiquity of 'biofilms'. They appear on almost every solid surface in contact with water bodies; they are responsible for the fouling of ship hulls and other marine installations like oil drilling platforms; they form in water pipes, on the surface of cooling tower heat exchangers, in institutional cooling systems and in waste-water treatment systems. They can also develop on animal and plant surfaces; thus dental plaque is one example of medical importance.

Microbial film has its own 'life cycle'. A very clean surface is coated first with a conditioning film often of protein molecules. Cells attach and microcolonies develop. These grow and coalesce, attaching to the surface firmly and forming a uniform layer. The latter increases in thickness. It often gets so thick that oxygen cannot penetrate to lower levels. The film can then become anaerobic. Often anaerobic metabolism can destabilise the film and a mature film can slough off leading to a second cycle of activity.

Our approach to using laboratory 'model' systems suggested that a 'steady-state' film model was needed that was maintained at a constant thickness so that it never became destabilised. Such steady-state systems are useful tools to investigate film properties. This is because such 'open' systems can readily be perturbed by varying a single factor and measuring the response of the system. A constant depth film fermenter was developed by A Tatevossian, R A Coombe, A Peters and the author in Cardiff. The latest version (figure 3a) contains 75 separate film plugs located in 15 removable film pans. The surface of the pans is constantly swept by a PTFE bar, while the film plugs are recessed a controlled amount. Once the plug space is filled with microbial film, the dimensions of the system are of course known. The fermenter is totally enclosed so it can be operated aseptically under any gas or nutrient regime. Sample pans can be removed and replaced aseptically without affecting the experiment. So far this system has been used to measure film growth (figure 3b) and to determine oxygen relationships using microelectrodes in a specially designed holder. In addition, film development has been followed by scanning and transmission electron microscopy.

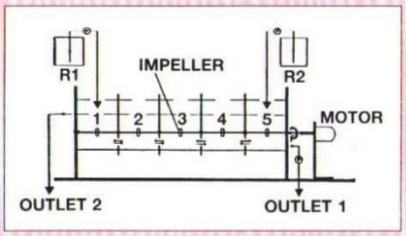


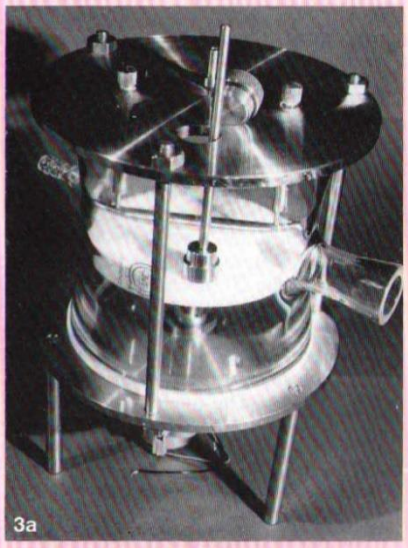
Figure 2: Sketch illustrating the principle of bidirectional exchange in the direct-coupled gradostat.

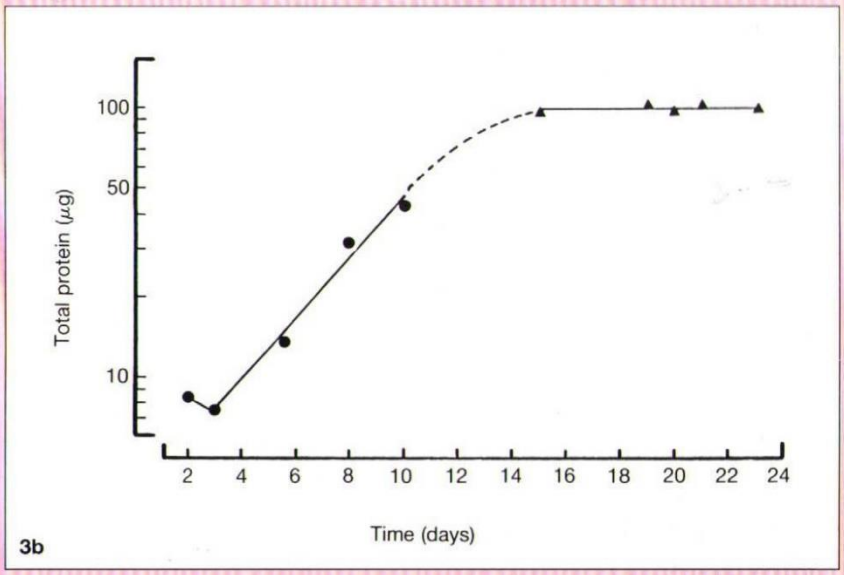
Figure 3: a: The constant depth film fermenter. The rotating PTFE disc can be seen, in which are located 15 film pans each containing five film plugs on which the actual film is grown. b: A typical growth curve for a natural river-water film community growing in the film fermenter. Results were a composite from two separate runs at different times of incubation.

This article has described just three types of microbial growth model which aim to reveal some of the properties of spatially heterogeneous microbal ecosystems under controlled conditions in the laboratory. To understand details of community structure and interactions it will be necessary to leave homogeneous systems like the chemostat behind: they will soon have outlived their usefulness!

Work on the gel-stabilised model systems was supported by grants from SERC's Biological Sciences Committee. Natural Environment Research Council grants and studentships have contributed to the development of the gradostat and of the film fermenter.

Dr J Wimpenny
Microbiology Department
University College, Cardiff





Superdeformed nuclei observed at Daresbury

The recent experimental observations of superdeformed nuclei at the Nuclear Structure Facility (NSF) at Daresbury Laboratory has caused considerable interest among nuclear structure physicists worldwide. Theory has predicted that under conditions of extreme stress caused by rapid rotation, some nuclei will adopt an elongated superdeformed shape with a major-to-minor axis ratio of 2:1. Experimental observation of these unusual states of nuclear matter has been sought for many years but, as Dr John Simpson relates, it has been made possible only recently, using the new generation of gamma-ray spectrometers pioneered at Daresbury Laboratory and Liverpool University.

The most direct way of studying these states, and indeed all high spin phenomena, is by measuring gamma-rays emitted by excited nuclei which are produced by the fusion of two heavy ions. At Daresbury, fusion products are formed when target nuclei are bombarded with high energy, heavy-ion beams from the 20 MV tandem accelerator at the NSF. In general, these products are produced with a great deal of angular velocity, which is enough to perturb the structure of the nucleus in a significant way. The nucleus loses most of its spin by emitting gamma-rays, each of which corresponds to the deexcitation of the nucleus from one state of high angular-momentum to another of lower angular momentum. In order to unravel the complicated gamma-ray spectrum produced in a reaction, sophisticated, multicoincidence, gamma-ray detection techniques are needed.

Physicists in the UK are world leaders in this type of spectroscopy and the latest, multi-detector, gamma-ray spectrometer employed is TESSA3 (Total Energy Suppression Shield Array). This spectrometer is the newest member of a family of gamma-ray arrays that have revolutionised the field of high-spin nuclear physics over the last five years. The spectrometer combines a crystal-ball calorimeter with a set of high-resolution, germanium detectors. The crystal ball consists of 62 hexagonal, bismuth germanate scintillation (high efficiency, low resolution) detectors which almost completely surround the target. It gives a measure of both the total number and total energy of gamma-rays emitted following a nuclear reaction, which in turn can be related directly to the spin and temperature of the nucleus.

TESSA3

In TESSA3, there are also 12 high-resolution, germanium semiconductor photon detectors, each of which is surrounded by a large volume, bismuth germanate suppression shield. The shield is used to suppress events in which photons are Compton-scattered out of the germanium crystal and which otherwise would produce a large unwanted background in the gamma-ray spectrum at energies below the photopeak. It is possible to build up a complete picture of all the excited nuclear energy levels involved in the de-excitation process by analysing a large number of events in which gamma-rays are detected simultaneously in several germanium detectors and in the crystal ball.

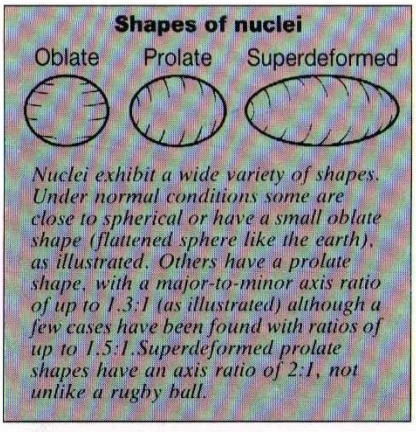
So far, superdeformation has been identified in one nucleus — dysprosium-152 (^{152}Dy). It was populated at high spin by bombarding a target of ^{108}Pd with a beam of 205 MeV ^{48}Ca ions.

About 2% of the ^{152}Dy nuclei produced are in the superdeformed state. The spectrum shows a series of 19 gamma-rays, spaced at a fairly constant energy interval of 47 keV, the correct spacing for the expected moment of inertia of a superdeformed shape. It can be established that these are emitted when the nucleus slows down from an angular-momentum of 60 units to 22 units. In this nucleus an angular momentum of 60 units corresponds to an angular frequency of about 2×10^{20} revolutions per second. The direct observation of a nuclear state with an angular-momentum of 60 units represents a 'quantum leap' forward in large angular momentum nuclear structure studies. The largest angular momentum previously reported was 46 units and recent advances had been in steps of only one or two units. Furthermore, 60 units is very close to the limiting value for any nucleus before it breaks up under rotational stress.

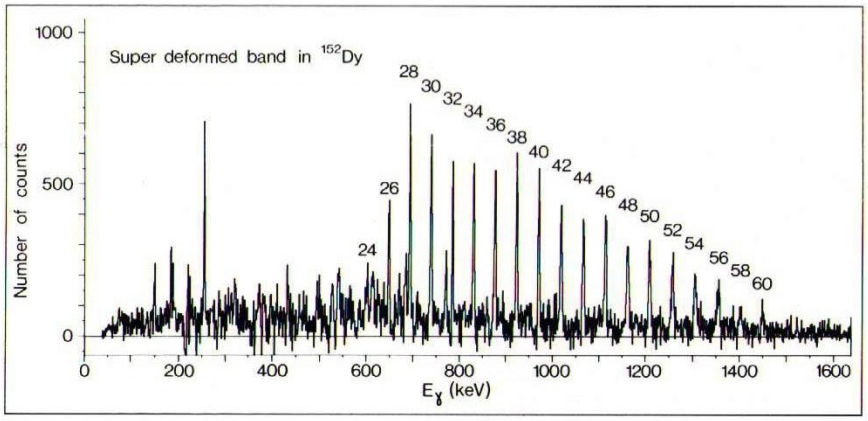
The final confirmation that the states observed in ^{152}Dy are indeed superdeformed came from a second experiment, again using the TESSA3 spectrometer, to measure their lifetimes.The data yielded very short lifetimes, of the order of femtoseconds (10^{-15} s), corresponding to an extremely large quadrupole moment, which is a clear signature of a superdeformed shape.

These observations herald the opportunity to study the nucleus — the only strongly interacting, many-body quantum system — in a new extreme condition. Such studies, already underway at Daresbury, are also being initiated at several European and American laboratories.

Dr John Simpson
Daresbury Laboratory



Nuclei exhibit a wide variety of shapes. Under normal conditions some are close to spherical or have a small oblate shape (flattened sphere like the earth), as illustrated. Others have a prolate shape, with a major-to-minor axis ratio of up to 1.3:1 (as illustrated) although a few cases have been found with ratios of up to 1.5:1.Superdeformed prolate shapes have an axis ratio of 2:1, not unlike a rugby ball.



TESSA3 spectrometer spectrum of gamma-rays in the superdeformed band in dysprosium 152.

Advances in ultrasensitive laser spectroscopy

A pioneering technique of ultrasensitive laser spectroscopy has been developed recently at Daresbury Laboratory's Nuclear Structure Facility (NSF), by scientists from Daresbury and the Universities of Birmingham and Manchester. Dr Derek Eastham explains why it was developed and how it works.

Laser spectroscopy at the NSF is mainly concerned with precision measurements of the shifts and splitting of visible atomic transitions (hyperfine structure) in radioactive isotopes. Although these effects are very small (typically a shift or splitting would be about 10^{-6} times the energy of the transition), they can be measured because of the extremely monochromatic nature of light from a tunable dye laser. The measurements provide valuable information about the shapes and sizes of radioactive atomic nuclei, particularly the latter which cannot be obtained by any other technique. Since the majority of the 2000 known isotopes are radioactive the development of more sensitive techniques to extend these measurements is an important part of the programme in several laboratories throughout the world. At the NSF the aim of the work has been to make measurements of proton-rich nuclei furthest from the line of nuclear stability. In these exotic nuclei, the balance between Coulomb and nuclear forces is quite different from that for stable isotopes and this may lead to unexpected behaviour. These isotopes can only be produced in very small quantities and hence a much more sensitive technique was required.

The FACS technique

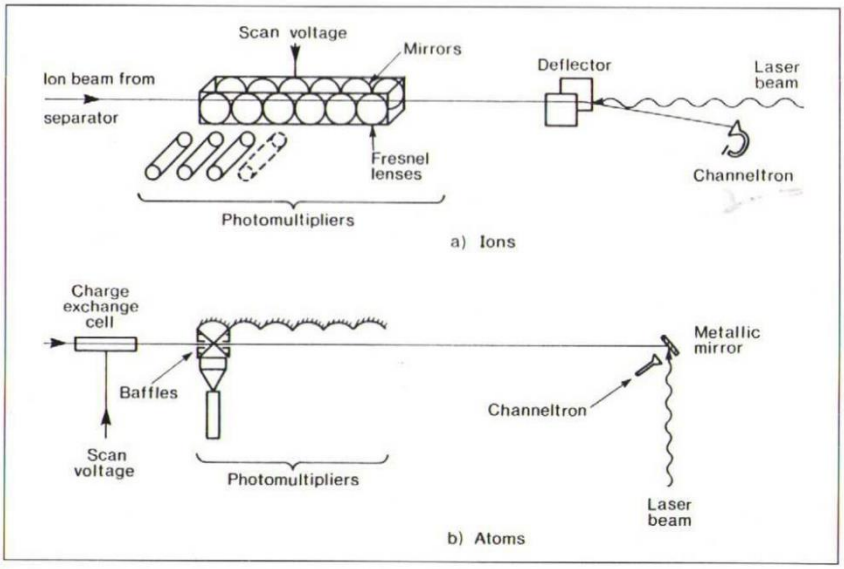
The basis of the new technique is shown in the figure and is known as FACS (Fluorescent Atom Coincidence Spectroscopy). It involves colliding a radioactive beam from the NSF isotope separator with a tunable dye laser beam. The radioactive isotope is produced by bombarding a target with a heavy ion beam from the NSF tandem accelerator. (For example in a recent experiment, radioactive strontium isotopes were produced by bombarding an iron target with a 160 MeV beam of sulphur ions.) The radioactive products are knocked forwards through a thin foil into the ion source of the isotope separator, where they are first thermalised before being ionised and accelerated to 30 keV. The accelerated beam is then mass-separated using a magnetic field and formed into an ionic beam or, if passed through a lithium vapour, it can be transformed into an atomic beam (figure (b)).

The basic arrangement shown in the figure is known as the collinear geometry. In the NSF experiments, the laser frequency is fixed close to an atomic or ionic transition and the velocity of the beam is altered by adjusting the voltage on the charge exchange cell (atoms) or on the light collector (ions). When the velocity is such that the Doppler-shifted laser frequency exactly matches the atom transition, photons are absorbed from the laser beam and subsequently spontaneously emitted in all directions, giving rise to a detectable signal in the photomultipliers. The number of detected photons depends on the number of atoms (or ions) in the separated beam. Experiments on stable isotopes are comparatively easy because atomic (ionic) beams containing greater than 10^{12} atoms a second can be produced quite simply. For radioactive beams the production rates are smaller but measurements (using only the scattered radiation) have been made at Daresbury and in other laboratories with beam intensities between 10^{6} and 10^{11} atoms per second. However, when the intensity drops to 10^{5} atoms a second these measurements become impossible because the resonantly scattered radiation (resonance fluorescence radiation) is obscured by a large background component of laser light scattered directly from slit edges and apertures.

The new technique developed at the NSF overcomes this problem. It involves the use of coincidence spectroscopy, an age-old technique in nuclear physics but one which has rarely been applied in atomic spectroscopy. Essentially, the resonantly scattered photons can be distinguished from the other unwanted photons by the simple expedient of demanding that a photon detected by the photomultipliers must be associated with an atom detected further downstream after taking into account the transit time in the beam tube. The sensitivity of the new technique is exceptional. Measurements have been made with as few as 50 atoms a second colliding with the laser beam, at least a factor of a thousand more sensitive than found at any other competing laboratory. The static atomic density from which the laser light is scattered corresponds to about 1 atom in 100 litres.

The technique has been initially applied to radioactive strontium nuclei and has produced some exciting results for the charge radius at the limits of nuclear stability. The increase in sensitivity means that whole new areas of the periodic table now become accesible and further experiments are in progress. Improvements in the method are underway so that, ultimately, it is hoped that the sensitivity can be increased to the magic figure of 1 atom per second.

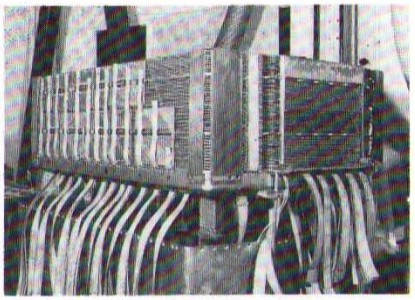
Dr Derek Eastham
Daresbury Laboratory



Arrangement for coincidence laser spectroscopy.

ALEPH detector in construction

Preparations for first collisions between electron and positron beams in the Large Electron Positron Collider (LEP), expected in the spring of 1989, are now in full swing. The physics regime at the Z^0 resonance formed in e^+e^- collisions at 92 GeV is expected to provide new tests of the now 'standard' model of electromagnetic and weak interactions and shed light upon unanswered questions such as the existence and mass of the sixth 'top' quark and the number of neutrinos in nature. As the collision energies of LEP increase in the longer term, there may be more surprises in store from the search for the symmetry-breaking Higgs particle, and in the study of W^+W^- production. Dr John Thompson of Rutherford Appleton Laboratory outlines progress on ALEPH, one of the detectors.



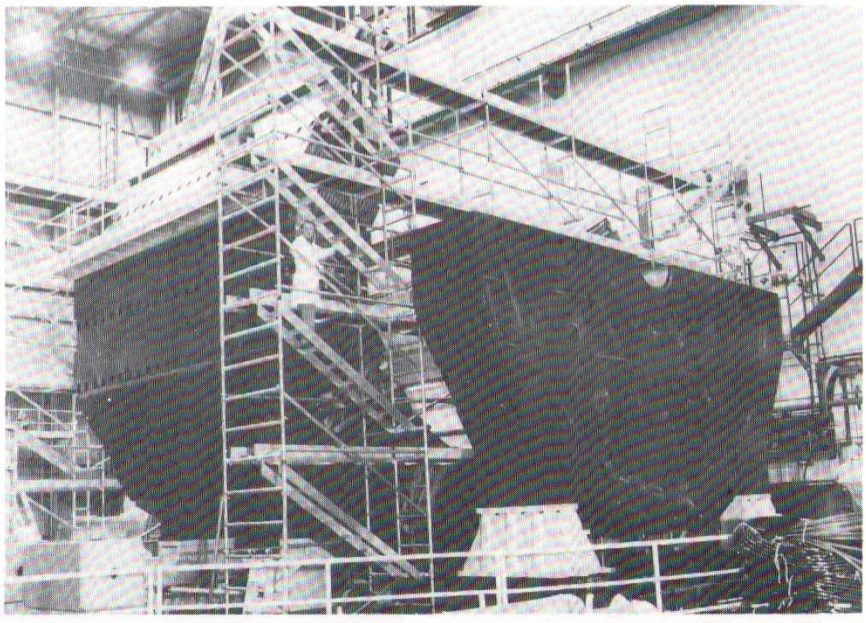
A completed electromagnetic calorimeter sector, or end-cap petal. It weighs 2½ tonnes and was assembled at RAL. The 45 layers of lead, the wire chambers and side wiring connections are clearly visible. The particles will enter downwards from the top face when the petal is installed in the ALEPH detector.

More than 90% of the 26 km circumference LEP ring has now been excavated leaving a section beneath the Jura mountains as the last remaining obstacle. The LEP injector has been commissioned, transferring electrons into an accumulator ring at 400 MeV where positron beams will eventually be stored. At four points equally spaced around the LEP ring, an even larger volume of the underground rock has been removed to create the large halls in which the experiments will be sited.

The domed ALEPH experimental hall is 19 m high, 20 m wide and 70 m long, located 120 m below the surface near the French village of Echenevex, 16 km by road from CERN's Meyrin site in Switzerland. Some intrepid physicists have already visited this freshly dug cave to gain a foretaste of their future working environment. Fortunately, all the experimental groups plan to establish their data collection rooms on the surface where, in the case of ALEPH, physicists might hope for inspiration from distant views of the Alps.

Just about half the UK particle physics community is involved in three of the four LEP experiments. Of the 28 widely scattered European institutes collaborating in ALEPH, seven are located in the UK: at Edinburgh, Glasgow, Lancaster and Sheffield Universities, Imperial College of Science and Technology and Royal Holloway and Bedford New College (RHBNC), and the Rutherford Appleton Laboratory (RAL). Major projects in the detector construction, data acquisition and off-line software were negotiated within the collaboration by physicists from these institutes.

Since approval of the experiment in 1983, the prototype phase for the mechanical hardware has been passed and some 50 UK physicists and engineers are now actively engaged in the production and testing of apparatus, and other related projects. As the start of LEP draws near, this number will increase towards 70 when more PhD students become involved and other physicists complete existing commitments. At present, the majority are based in their UK institutes where the production activity is centred. However, five UK physicists are already at CERN, engaged in the development of the data acquisition system and off-line analysis programs for 'event' reconstruction and Monte Carlo simulation. These projects cross boundaries between the different particle sub-detectors which form the ALEPH detector and require a team effort in the early phase.



The ALEPH magnet iron yoke being assembled at CERN. The barrel and end cap sections are made of laminated iron. Both sections will have detectors placed in the gaps between the laminations to allow detection of showers of particles generated from the interactions of hadrons in the iron. (Photo CERN).

The ALEPH detector will enable precise measurements of electrons and photons to be made even when they are produced inside dense jets of other particles. These measurements are made by the sub-detectors which reside within an axial magnetic field of 1.5 Tesla produced by a superconducting solenoid 5.3 m in diameter and 6.3 m long. They consist principally of a central Time Projection Chamber (TPC) for the recognition and momentum determination of charged particles, and a fine-grain electromagnetic calorimeter around its periphery which has almost complete angular coverage for photons and electrons from the collision region. This calorimeter has 74,000 elements which has taxed the ingenuity of physicists and engineers at Glasgow University and in the Physics Apparatus Group of RAL's Instrumentation Division. They have the task of providing 24 sectors of this calorimeter, supported by the workshops at Lancaster, RHBNC and Sheffield. The calorimeter sectors contain 1,080 sandwiched assemblies of wire planes, lead sheets and printed circuits, involving the machining of 27,000 aluminium extrusions to high tolerances; stretching 230,000 fine 25 μm diameter

wires to the correct tension; and soldering 1.1 million connections to the printed circuits! By the end of 1986, almost half of the wire planes had been built and the first sector is now being calibrated as a fully operational calorimeter using cosmic ray muons in a test facility at RAL. Energy deposited in the calorimeter is measured as electric charge stored in some 220,000 channels of analogue electronics which is later digitised on transfer to a Fastbus system.

To save costs, the electronics have been substantially multiplexed. The RAL electronics group has developed a 16 channel monolithic chip designed in CMOS technology and fabricated by outside industry. If successful, these devices may be adopted in place of some conventional but more expensive hybrids originally developed as fallbacks.

Another major sub-detector for the ALEPH experiment is under construction at Imperial College. This is a 2 m long cylindrical drift chamber which will be located around the beam vacuum pipe close to the collision region. Its primary function is to reconstruct charged particle tracks a few microseconds after an interaction has occurred, to trigger the remainder of the ALEPH detector. In addition, its multi-layered wire readout provides enhanced pattern recognition and reconstruction accuracy for nearby tracks. Special studies have been devoted to mechanical long-term reliability and the fast-timing electronics required. This chamber must be available in late 1987 ready for installation tests with the large TPC being built at CERN.

Finally, UK physicists at Glasgow and RHBNC have already developed strong links with the TPC project. Glasgow physicists are collaborating with Mainz University in West Germany to provide a neodymium YAG laser system which will beam ultraviolet light into the TPC gas volume to create straight tracks by ionisation for calibration purposes. Physicists at RHBNC are constructing a sophisticated electronics processor which will rapidly reconstruct the origin of charged particle tracks from the TPC data. This will remove background interactions unresolved by the Imperial College chamber and hence avoid detailed processing of otherwise unwanted 'events'.

The ALEPH detector will cost about 60 million Swiss francs (1983 prices) of which the UK is contributing 18% over five years. With the design and procurement phase of this period largely passed, the physicists and engineers look ahead with some excitement to the prospect of performance testing of their final pieces of apparatus followed by real physics in just over two years' time.

Dr J C Thompson
Rutherford Appleton Laboratory

Hydrolytic weakening of quartz

The strength of strong solids can sometimes be dramatically reduced by the presence of small concentrations of impurities. A striking example is quartz. A group at Exeter University under Dr Bob Jones, supported by a Materials Committee grant, have explored the mechanism of the hydrolytic weakening of quartz.

Quartz when dry has a yield stress of approximately 1 GPa at 1300° C (under a confining hydrolytic pressure). This drops to about 100 MPa at 600° C for samples containing several hundred parts per million of water.

To test existing theories, it was essential to examine the electronic structure of dislocations, kinks and the water defects. The dislocations in dry and wet quartz were modelled by using a simple short-ranged interaction potential fitted to the vibration spectra of alpha-quartz. In dry quartz, low-energy dislocations with no dangling bonds were found; these have small core energies of between 2 and 4 eV/repeat distance. Double kinks on a basal 60° dislocation, however, have formation energies of 5 eV and a migration energy of at least 4 eV. These figures explain the immobility of dislocations in dry quartz and are comparable to experimental estimates of formation energies of 3 ± 1 eV and a migration energy of 6 eV.

Neither the double kink nor the straight dislocations have energy levels in the forbidden gap. The high double-kink formation energy is due to bond extension (3%) at one kink leading to a substantial strain field. If this bond is broken by a water molecule to form a hydrolysed bond ≡ Si-OH...H-O-Si ≡ then the two silicon tetrahedra at each end of this hydrolysed bond can separate and release a substantial amount of the strain energy. Calculations have revealed that the formation energy of the double kink could then be reduced to about 1 eV; the migration energy is also likely to be substantially reduced. The experimental estimates for these quantities in wet quartz are 0.3 eV and 1.4 eV respectively.

These research findings quantified and extended the Griggs-Blacic-Frank model of hydrolytic weakening, and have implications for a number of other research areas; for instance, the fact that the rate of growth of oxide films on silicon is dependent upon the dryness of the oxygen atmosphere suggests the process may be influenced by a hydrolytic weakening effect in the oxide.

The strain-releasing effect of certain impurities is also likely to promote dislocation motion in other strong solids.

A better understanding of the deformation processes in quartz may ultimately assist in the design of ceramic materials for engineering purposes.

Dr R Jones
Department of Physics
Exeter University

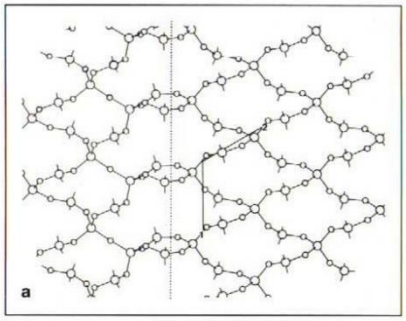


Figure (a): Projection of the atoms of a basal 60° dislocation in alpha-quartz on to the c-plane. The dotted line marks the dislocation core containing a circular channel. The Burgers vector is parallel to the full line through 2.

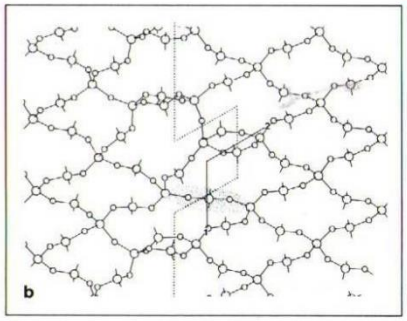


Figure (b): Projection of the atoms surrounding a double kink on the dislocation illustrated in (a). Note the advancement of the circular channel. Bonds in the shaded region are highly strained and are easily broken by a partially dissociated water molecule releasing a large strain energy.

Collaboration in thermo-fluid mechanics at Sussex

In the *SERC Bulletin* Volume 3 No 5, Summer 1986, accounts were given of the general research programme jointly supported by Rolls-Royce Ltd and SERC, and also of the work of the Thermo-Fluid Mechanics Research Centre (TFMRC) at Sussex University, which contributes to the cofunded programme. In this article, Professor Fred Bayley and Dr Mike Owen enlarge a little on the TFMRC activity and, particularly, highlight the extent of the industry-university collaboration which has resulted from the existence of the Centre.

The TFMRC building contains five test cells, a number of small laboratories, a compressor room, a computer room, workshop and offices. The soundproofed test cells currently house the principal test rigs for the experimental programme and are well equipped with instrumentation. The Centre has its own PDP 11/44 computer for data logging and analysis, as well as links to the University's VAX machines and the Cray at the University of London Computer Centre. The number of staff in the Centre has increased from seven at its foundation to about 20 and, to provide acceptable working conditions for this number, the University has recently funded the installation of an upper floor to give more office space.

As described by the earlier *Bulletin*, almost all of the work in TFMRC is concerned with heat transfer and the associated flow processes in advanced gas turbines. Complementary experimental and theoretical studies of the complex phenomena associated with rotating cavity and rotor-stator systems found in modern engines account for about three-quarters of the current programme. The remainder includes investigations of blade heat transfer and the problems of the small radial-flow gas turbine. It was the intention and, indeed, the charge at the foundation of TFMRC in 1977 that a major part of its suppport should come from industry: of the roughly £2 million of income since its inception, one half has come from industry and the other from SERC.

Currently an award under the Cooperative Research Grant Scheme, made jointly by GEC-Ruston Gas Turbines, Rolls-Royce Ltd and SERC, is the principal source of funding. This scheme has been most fruitful in encouraging not only collaboration between industry and the academic sector but also inter-company cooperation. The regular two-monthly meetings between members of TFMRC and the industrial collaborators, at which results from and plans for the research programme are discussed, have allowed exchanges of view between the industrial partners that are at least as significant as those involving the academics.

As well as research cooperation with the British manufacturers, there has been continuous collaboration between the TFMRC and European gas turbine companies. Sulzer, the Swiss manufacturer of industrial gas turbines, participated with their British competitors, GEC-Ruston Gas Turbines, to fund early work on the rotor-stator programme and have recently invited further cooperation. Motoren und Turbinen Union (MTU), the German aero-engine manufacturer that collaborates with Rolls-Royce on many projects, has funded part of our rotating cavity programme in the past. Currently MTU finances the transient analysis of engine test data in the TFMRC, and discussions are currently in progress to consider ways in which MTU can contribute to the future rotating disc programme. Although in the past we have had no research contacts with American companies, there have been enquiries from a major American aero-engine manufacturer about the prospects of cooperation with the TFMRC on gas turbine cooling problems.

The new programme on small gas turbines began in collaboration with the Aisin Seiki Company, a subsidiary of the Japanese Toyota Corporation. Currently discussions are in progress to explore the possibility of Rolls-Royce also participating in this project. The presence on the Sussex campus of the Aisin Research Laboratory was a direct consequence of the existence of the Centre. Aisin Seiki's principal research interest in their European project is energy conservation, to which the activities of the TFMRC are clearly complementary. The company was also impressed by the low-cost design developed and implemented by the TFMRC architect who also designed the research laboratory of the British company Eurotherm International, the latest addition to Sussex University's Science Park.

Thus from the original grant in 1977 by the (then) Science Research Council for the creation of the TFMRC has sprung a major industry-academic and, indeed, company-company collaboration. The transfer of technology from TFMRC to the UK gas turbine industry was recognised by the British Technology Group in 1985 through the award of the first prize of £25,000 in the Academic Enterprise Competition. It is an award for which credit can be shared by past and present members of the TFMRC, by our sponsoring companies and by SERC.

Dr Owen and Professor Bayley examining the Mark I rig which is currently being used to investigate the effects of real engine geometries on fluid flows and heat transfer in rotating cavities.

Professor F J Bayley
Dr J M Owen
School of Engineering and Applied Sciences
Sussex University

Materials for maskless implantation of silicon

Maskless doping of sub-micron areas of Very Large Scale Integrated (VLSI) microcircuits has been made possible by the development of the Culham-Dubilier high-intensity liquid-metal ion source. The aim of a programme of research at Manchester University and the University of Manchester Institute of Science and Technology with IBT-Dubilier, funded by a Cooperative Research Grant from the Materials Committee, was to obtain the basic materials information on suitable alloys and needle materials, so that arsenic and boron could be implanted directly into silicon by means of the new source. The programme is described here by Dr D G Lees and Dr F H Hayes.

The basic features of the Culham-Dubilier liquid-metal ion source are shown schematically in figure 1. A needle with a tip radius which is normally 1-10μm is covered by a film of liquid metal. A beam of positively charged ions is produced by applying a voltage (typically 4-10 kV) between the needle and the extractor. The beam is then focused by suitable lenses.

The materials requirements are:

- The vapour pressure of the molten metal must not be greater than 1×10^{-3} torr.
- The needle must be wetted by the molten metal but not eroded by it.

Problems arise with the dopants arsenic and boron, which are of particular interest for silicon, because the vapour pressure of arsenic is too high and the melting point of boron is so high that it would attack the needle material. The solution in both cases is to select alloys of these elements which have lower melting points. The dopant is mass-separated from the resulting ion beam.

Arsenic

The platinum-arsenic system was chosen for this source. The arsenic vapour pressure was measured over the Pt-28at%As alloy because this has the lowest melting point.

The results of the vapour pressure measurements show that the vapour pressure at the eutectic temperature is approximately 100,000 times lower than the maximum tolerable pressure and that the liquid-metal ion source can be operated safely at temperatures well above the eutectic temperature. Metallographic work showed that tungsten is suitable for use as a needle material with this alloy.

Boron

The platinum-boron system was chosen for this source. The composition of interest is at 28at% boron where the melting-point is lowest. Tests were carried out to determine whether rhenium wire (a possible needle material) was attacked when it was heated in this alloy.

When the wire was heated in the alloy for one hour at 790°C, there was no detectable attack. When it was heated for 28.5 hours at 950°C (a very severe test), the result shown in figure 2 was obtained. Some attack has occurred and pieces of the needle can be seen in the alloy. However, the attack has not been very great and when account is taken of the fact that the temperature was much higher than the melting-point of this alloy, rhenium appears to be a promising needle material. It is interesting to note that when a different batch of rhenium wire was used, a quite different result was obtained. The result of heating this wire for 8 hours at 800°C is shown in figure 3. The alloy has intruded into the rhenium and the wire has swollen. Figure 4 shows the mass spectrometer results from the Pt-28at%B alloy when it was run in a liquid-metal ion source. The boron ions constituted 23% of the output. Results so far are encouraging.

Computer calculations of ternary phase diagrams

If a third element is added to a boron alloy, the melting-point may be lowered still further and the stability of the needle material in such an alloy may be increased. Finding by experiment whether such alloys exist is very time-consuming because of the large number of possibilities in a ternary system. In the Department of Metallurgy and Materials Science at Manchester there is considerable expertise in computing phase diagrams, thus reducing the work involved in finding the compositions which are of interest. Computations have been carried out on boron-containing alloys; they indicate that ternary alloys exist which melt at lower temperatures than binary alloys. This is a very promising field for further work.

For further information on this project, contact:

Dr D G Lees or Dr F H Hayes
Joint University and UMIST Metallurgy Building
Grosvenor Street, Manchester M1 7HS
Telephone Manchester (061) 236 3311

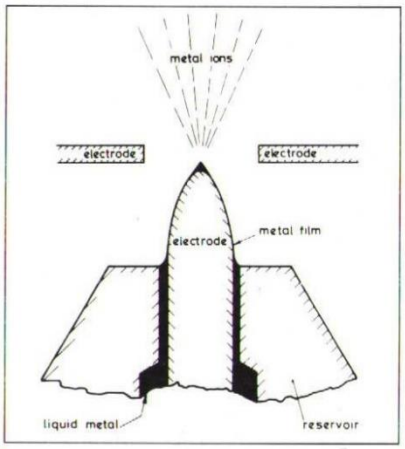


Figure 1: Schematic diagram showing the basic features of the Culham-Dubilier liquid-metal ion source.

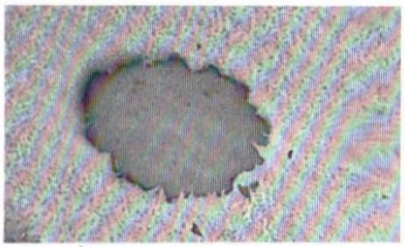


Figure 2: Cross-section of rhenium wire after heating in Pt-28at%B for 28.5 hours at 950°C.

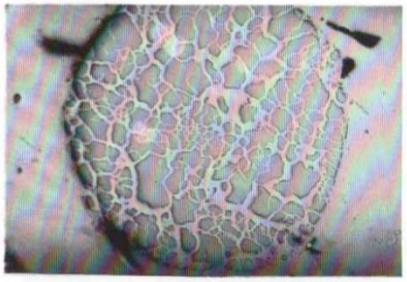


Figure 3: Cross-section of rhenium wire after heating in Pt-28at%B for 8 hours at 800°C. The original diameter of the wire was nominally 0.5mm. Note that this wire and the wire in figure 2 came from different batches.

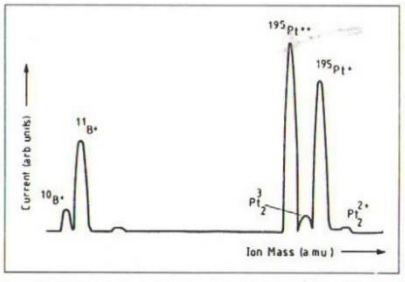


Figure 4: Spectrum of the output from the Pt-28at%B alloy in a prototype ion source. The B^{2+} output is less than 1% of the total current in the beam and is not visible in the diagram. The $^{11}B^{+}$ and $^{10}B^{+}$ outputs constitute respectively 19% and 4% of the total current.

High strength for low-cost roads

A study of the performance of soils suitable for low-cost road making has produced some surprising results. It is described here by David Toll of Imperial College of Science and Technology.

Most people in developing countries live in areas served by poor roads, often made impassable by the weather. Without access to some form of all-weather road system the populations of these areas are unable to contribute to or benefit from the development process.

An extensive range of locally occurring soils, many of them laterites (iron-cemented residual soils), are used for the construction of unsurfaced low-volume roads. But the cost of maintenance is rising sharply and the steeper sections of such unsurfaced roads usually become impassable during periods of heavy rain. Moreover, most local materials suitable for unsurfaced roads do not comply with recognised specifications for bituminous surfaced roads and, if used in the normal way, extensive failures occur. The provision of some form of bituminous surfacing is therefore an urgent requirement.

Some of the local lateritic gravels have, however, performed satisfactorily particularly when the road is left unsurfaced for one wet season before laying the bituminous top. The explanation for this satisfactory behaviour was not known and little research had been carried out to investigate it. Yet the ability to identify such soils and specify their placement has obvious important cost implications and associated benefits to developing countries.

A large collaborative programme was established to study existing experimental roads in Kenya and Malawi, investigate the fundamental soil properties and develop suitable specifications and design methods for future low-volume, all-weather roads.

Field testing in Kenya (Photo: ICST).

The programme is being coordinated by Henry Grace, retired Senior Partner of Scott Wilson Kirkpatrick and Partners. Funding has been received from the Overseas Development Agency, the Leverhulme Trust and SERC. Contributions in kind have been made by the Transport and Road Research Laboratory, Kenya Ministry of Transport, Nairobi University, Scott Wilson Kirkpatrick and Partners and Henry Grace and Partners.

The fundamental laboratory study on some Kenyan lateritic gravels was funded by SERC's Environment Committee and was carried out in the Department of Civil Engineering, Imperial College of Science and Technology. Besides routine mechanical and mineralogical testing, some highly specialised testing was carried out using moisture suction measurement and control.

These studies have revealed that the good performance of the soils stems primarily from their particle size grading and the nature and distribution of the clay fraction. The form of grading ensures ease of compaction to high densities. The tests on unsaturated samples show that the high suctions give rise to great rigidity and strength. However the high densities ensure that, when saturated after heavy rainfall and subjected to traffic loading, the soils behave in an undrained manner in which dilation during shearing is suppressed and high rigidity and strength is kept.

The research has identified the important features which are essential for good performance of road base materials in low-volume roads. Contrary to widely held views, it is not the 'self hardening' properties of laterites which give rise to good performance but the grading of the material. Thus other naturally occurring materials may be equally satisfactory. However, to be able to establish more closely the boundaries between good and poor behaviour, it will be necessary to test a wider range of materials both in the laboratory and in field trials.

For further information on this project, contact:

D G Toll
Department of Civil Engineering, Imperial College of Science and Technology

Pavement research at Nottingham

The Pavement Research Group at Nottingham University has worked on a variety of practical research projects involving joint SERC/industrial support over recent years and that work has lead to well defined improvements to materials and design techniques for roads, writes Professor Stephen Brown.

An extensive project with the Mobil Oil Co Ltd led to the development of a computer program to design asphalt pavements based on elastic theory and mechanical properties of the constituent materials (figure 1). The program (ANPAD) was used to assist in the preparation of Mobil's Asphalt Pavement Design manual for the UK. Background experimental work included laboratory testing of a wide range of bituminous materials for the main structural element of a pavement, the road base. The tests concentrated on resistance to permanent deformation, which causes rutting failures in highways, and elastic stiffness, which defines the load-spreading ability of the material *in situ*. The results suggested how British Standard materials could easily be modified to provide longer life and improved performance in the road. The background work on aggregate gradings also pointed the way to a possible method for designing asphalt mixtures and developing end-product laboratory tests. These ideas are presently being pursued in a new SERC/Mobil Cooperative Research Grant, in conjunction with the US National Asphalt Pavement Association.

The Research Group made a large contribution to the recently completed major research investigations into the applications of polymer grids for reinforcement in civil engineering as part of a SERC/Netlon Ltd cooperative research programme. The Nottingham work involved experimental studies of grid reinforcement for asphalt and led to significant conclusions regarding the potential benefit for this technique. These included control of cracking and rutting in asphalt layers, both for new construction and overlays to existing pavements. Of particular interest was the finding that traffic-induced reflection cracks in new asphalt layers placed above existing cracked or jointed pavements could be eliminated by use of a grid reinforcement placed immediately over the old pavement (figure 2). Fatigue lives of typical asphalt mixtures with respect to cracking failure were found to be increased tenfold and, when the grid was placed in the correct position within the pavement, lives to a critical rut-depth could be extended by a factor of three.

With the gradual move from new road and airport construction towards maintenance of existing facilities, the Research Group has become increasingly involved with structural evaluation of pavements and the problems associated with their rehabilitation. A grant was awarded by the Environment Committee to develop the theoretical and computational ideas necessary for interpretation of field data obtained with a device known as the Falling Weight Deflectometer. This equipment is relatively new to the UK and allows the deflected shape of a pavement surface to be very accurately measured when a transient load is applied simulating a moving truck wheel. The computational developments allow the effective elastic stiffness of each significant layer in the pavement to be determined.

Research on various aspects of pavement foundations, which include the soil and unbound granular layers at the bottom of a road, is proceeding on a broad front. Work to date has clarified potential roles for geotextiles and the significance of grading, density and water content in granular materials. *In situ* permeability testing and measurement of pore pressure forms part of the site work on this project, supported by SERC and ICI Fibres.

The Research Group has been involved in a large number of field trials relating to various aspects of its research. These have all involved close collaboration with highway authorities and contractors and have generally assisted in extending ideas from the laboratory scale to engineering practice. A Department of the Environment/SERC - funded project presently under way is providing a unique opportunity to study the deterioration under traffic and environment of 16 different road constructions on a site in Yorkshire.

The Pavement Research Group at Nottingham has been active since 1954 and was recently awarded a Department of Trade and Industry/SERC Teaching Company Scheme Grant, with Scott Wilson Kirkpatrick and Partners, in order to allow the transfer of its research knowledge into engineering practice on a larger scale than had previously been possible. The scheme has led to the formation of a specialist consulting firm,

SWK Pavement Engineering, located on Nottingham University's Science Park, and its activities have significantly assisted in the development of new research ideas within the Pavement Research Group.

Professor S F Brown
Department of Civil Engineering
Nottingham University

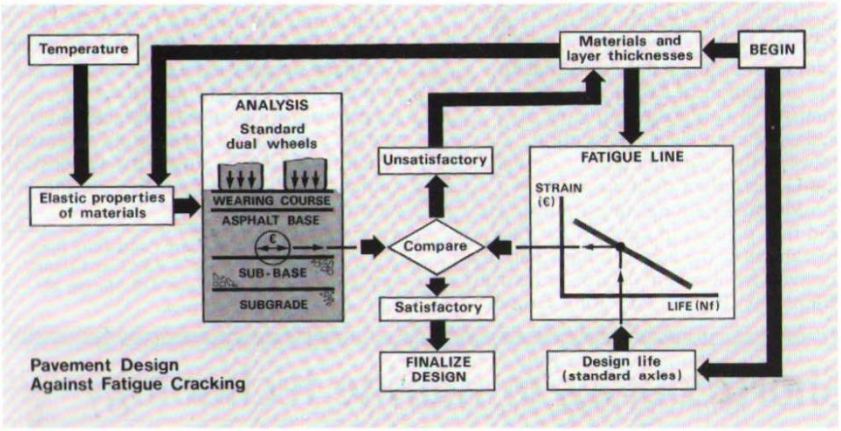


Figure 1: Pavement design against fatigue cracking.

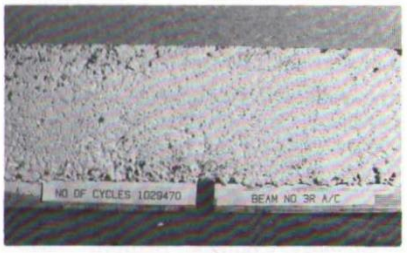


Figure 2a: Reinforced overlay

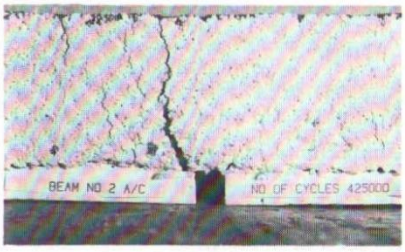
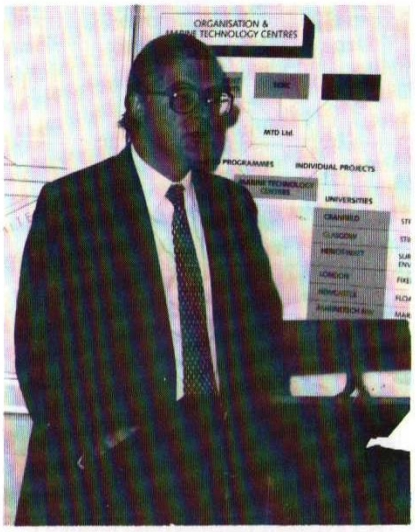


Figure 2b: Unreinforced overlay

The Marine Technology Directorate Ltd launched



The Rt Hon Kenneth Baker, Secretary of State for Education and Science, speaking at the launch of MTD Ltd.

The Marine Technology Directorate Ltd (MTD) was launched in London as a private company under the patronage of the Fellowship of Engineering on 20 October 1986.

Speaking at the launch, the Rt Hon Kenneth Baker, Secretary of State for Education and Science, said that the transformation of MTD into a private company was a positive means of achieving even closer assocation between the academic sector, industry and Government in an area of considerable national importance. He said that pledges of support for the operations of the new company had been received from seven* major industrial companies; Britoil, BP, John Brown Engineers and Constructors Ltd, Conoco UK Ltd, Esso UK Exploration and Production Ltd, Shell UK and George Wimpey plc. On the Government side, pledges of support had been received from the Department of Energy, Ministry of Defence and the Department of Trade and Industry. In addition, SERC would also provide support for the new company so that the relative contributions of industry, SERC and Government would be in roughly equal thirds.

Mr Baker said he was confident that MTD Ltd would help to ensure that Britain would always have world class products and services in marine technology. He praised the work of the Directorate, formed in 1977, in coordinating a wide range of ocean-related research and training activities and in forging links between academic researchers, industry and Government. Mr Baker said the occasion gave him the opportunity to stress again the fundamental importance of engineering and the application of science to Britain's future national well-being.

Referring to his announcement in July that the Government is to set up a Coordinating Committee on Marine Science and Technology (CCMST), Mr Baker said, "I look forward to seeing the Company operate in as unfettered a way as possible consistent with the framework of the national strategy for marine science and technology research which the CCMST, under my general guidance, will develop in the coming months and years".

**Since the launch, two more companies have joined the new enterprise — The Gas Council (Exploration) Ltd and Total Oil Marine plc — and others are expected soon.*

In relinquishing overall responsibility for MTD, Professor Bill Mitchell, Chairman of SERC, emphasised the successful role of MTD over the past nine years in coordinating multi-disciplinary research programmes and directing them towards problems related to working in the ocean environment as well as developing confidence between the academic community and industry. During this nine year period SERC had invested some £40 million in building up the research capability, in establishing seven marine technology centres and in supporting research programmes encompassing marine resources, physical ocean environment, ocean structures and materials and underwater working.

Professor Mitchell said that he hoped that the cut-backs in offshore exploration and new offshore field development brought about by the lowering of the oil price might provide an opportunity for reflection on the considerable benefits to be gained by industry of cooperation in precompetitive research by utilising the university expertise in areas of high-risk research but which might lead, in the longer term, to more cost-effective developments.

Lord Caldecote, immediate past-president of the Fellowship of Engineering, who gave support to what he saw as an exciting new initiative said, "The formal arrangement with MTD Ltd is that we shall be a member of the company, at a nominal subscription, but our strongest link will be maintained through the Chairman who is appointed by the Fellowship in consultation with ordinary members of the company".

Admiral Sir Lindsay Bryson has been appointed Chairman of MTD Ltd and the Director and Chief Executive is Mr Michael Adye who has been MTD's Director since its inception in 1977 under the auspices of SERC. Of the company's immediate and future role Sir Lindsay said, "We shall aim to develop the national capability in ocean-related activities through the support and management of research and the promotion of education and training in marine technology. An early task of the new company will be to identify priority areas for jointly funded research topics and to set in place a new programme of marine technology research by July 1987. This will include both fundamental and higher-risk strategic research in areas of national importance".

Short courses in marine technology

Between February and December 1987, some 30 short courses have been approved by the Marine Technology Directorate (MTD Ltd), in subject areas covering:

- geology and petroleum engineering
- corrosion and corrosion prevention
- inspection and non-destructive testing
- design and construction
- structural reliability and safety
- underwater engineering
- offshore materials
- marine mineral resources
- dynamics and fluid flow
- instrumentation, and
- project management

The courses are being held at eight universities and institutes around the country. Full details are given in *Short courses in marine technology 1986/87,* copies of which are available from:

Mr J M Stuart, Cranfield Institute of Technology, Cranfield, Bedford MK43 OAL; telephone Bedford (0234) 750111 ext 2544.

Making the best use of computers in managing production

Computers in factories do not only control manufacturing equipment such as robots and machine tools, they are also used to help the production manager. He has to make complex decisions about sequencing and timing production activities to satisfy often competing priorities such as meeting delivery deadlines, using resources efficiently, minimising stock levels, and maintaining production quality. To help him make these decisions, computer-aided production management (CAPM) products have been used for a long time.

Reasons for study

In order to refine research policy, the ACME Directorate decided to study CAPM use in UK manufacturing industry. A small number of academics was contracted to examine in depth CAPM use in 33 firms. The firms were selected so as to achieve a balanced sample by industry sector, company size, sophistication and complexity of the manufacturing control problem and so on. The data from the surveys were analysed by Directorate staff with expert help. Some important CAPM suppliers and consultants were also interviewed.

Conclusions

CAPM systems, properly designed, installed and used, promise to optimise the variables listed above for maximum efficiency of the enterprise. The results of the study* showed clearly that many CAPM users were not getting the benefits which are theoretically possible.

The time taken to achieve reasonable success with CAPM was often very long — up to seven years. Making the links between individual CAPM subsystems and between CAPM and other factory computer systems often presented serious difficulties. The latter goal — computer integrated manufacturing (CIM) — is industrially very important and central to ACME's research effort.

The study confirmed that the reasons for this state of affairs are many and complex. They include:

- the difficulty of combining human judgment with computer-generated information. This includes both lack of faith by users in 'opaque' algorithms, and inadequate consolidation of data into a comprehensible form;
- inconsistent linking of control loops;
- lack of timely and accurate feedback of information to the computer system, and
- inadequate skills and training.

A distinct learning curve was identified for firms progressing up the ladder from installation of stand-alone CAPM subsystems to full CIM. The most important issues at each level are different (see box).

New research goal

CAPM research supported by ACME has concentrated on producing new techniques for specific CAPM subsystems. On the basis of the study, ACME concluded that this emphasis is not directly relevant to current manufacturing problems. The central industrial need is to help manufacturing firms realise the benefits theoretically achievable from using *existing* CAPM technology. Thus the Directorate has launched a new research initiative whose goal is to produce and disseminate practical *methodologies* for the design, implementation and operation of CAPM systems.

Consortium approach

The production of methodologies of this kind demands contributions from a variety of disciplines such as production engineering, management science, computer science and human and organisational behaviour.

CAPM study findings

Degree of integration:	*Key issue*
No integration of CAPM subsystems:	*Accurate data*
Partial integration of CAPM subsystems:	*Timely data*
Full integration of CAPM subsystems:	*Shared data definitions*
Integration of CAPM with manufacturing system:	*Simplified and unified design of material flow and CAPM systems*

Thus multi-disciplinary research consortia are being formed from different academic departments and institutions to address all the aspects involved in implementing CAPM successfully. In each case, one group is charged with coordinating and disseminating the consortium's efforts.

The factors involved in adopting CAPM will vary according to the user firm's business — its production technology, market, product, raw materials, length of production runs and so on. We aim to produce methodologies for specific industrial 'sectors' which have several of these factors in common. Possible examples of sectors whose needs could be tackled separately include:

- small firms capable of using 'package' CAPM software;
- firms manufacturing bespoke products to order; and
- garment manufacturers.

Linking with industry

Research of this kind is valuable only if it meets a real industrial need in a practical way, and is organised in a way that maximises the chance of transferring the techniques developed to those who will use them. Each research consortium should, the Directorate believes, collaborate with CAPM users from the relevant industrial sector and with a 'vendor' partner. By 'vendor' we mean an organisation which would use improved CAPM implementation methodologies in its business. Examples are CAPM software suppliers and manufacturing systems consultants and designers.

Progress

Several CAPM research consortia are being formed and are expected to receive grant support soon. Much interest has been shown by potential vendor partners, one hundred of whom were represented at a special conference held by the Directorate in July 1986.

If you want to know more about the thinking behind the initiative, to comment or to participate, you can get a copy of the report from the ACME Directorate at SERC's Central Office in Swindon (ext 2475 or 2550).

J P Monniot

* *A study of the state of the art in computer - aided production management in UK industry*, J G Waterlow and J P Monniot, SERC, April 1986 ISBN 0 901660 85 X

SERC & BEST database

BEST, which stands for British Expertise in Science and Technology, is intended to be the national database of research and expertise in the UK's universities, polytechnics and Government research establishments. It is hoped that industry and other organisations will subscribe to it and thus become better informed about the UK's scientific and technological expertise. Longman Cartermill, who own BEST, is part of the Longman Group, one of the world's leading publishers and suppliers of technical, scientific and industrial information.

The establishment of an effective database of UK research and development will, SERC believes, be a crucial step forward in the drive to help industry get the best out of the current national research effort. SERC has been increasingly concerned over recent years to promote effective links between academic groups and industry, and has itself been active in this area through initiatives such as Cooperative Research Grants, Cooperative Awards in Science and Engineering and the Teaching Company Scheme. There is still much to do in putting over the significance of the research it supports to companies where the results can best be used to benefit UK industry. SERC feels that the BEST database should have a major influence in helping to disseminate information, particularly to small and medium-sized companies which are often unable to provide their own research facilities and need ready access to relevant academic expertise.

SERC has provided BEST with the basic data on its research grants in return for access to the database for its own internal purposes in servicing its Boards and Committees. The most likely applications of BEST by SERC will be:

- ☐ for choosing referees on research grant applications and for identifying potential members for peer review committees;
- ☐ for assisting the appraisal of new grant applications by providing additional information about support given to applicants from alternative sources;
- ☐ for answering questions from Government and for providing briefings in general terms about scientific research activity in the UK;
- ☐ for strategic planning purposes, for analysing British effort in areas of special initiatives and for choosing such areas.

SERC welcomes the opportunity for collaborating with the BEST database both as a means for putting its research grant information across to as wide an audience as possible, and for use as a planning tool in developing its own future policies and practices. For these reasons it applauds and supports the BEST objective to make the database as comprehensive as is possible, for maximum benefit to all users.

For further information on the BEST database, contact Mr M T Tobert, Longman Cartermill Ltd, Technology Centre, St Andrews, Fife KY16 9EA. SERC's contact point with BEST is Mrs M A G Veal, SERC Central Office, Swindon, ext 2177.

From research to engineering design

The Design Council has recently opened a large exhibition centre in the Haymarket, London, called the Innovation Centre, in which a continually changing display of the latest ideas and technologies from the widest possible range of fields can be exhibited. Special emphasis is given to technological and engineering innovations, with the aim of demonstrating to industry and the nation the importance of the research, development and design process.

As part of its Engineering Design Initiative (*SERC Bulletin* Volume 3 No 4, Spring 1986), SERC is sponsoring a six-week exhibition entitled ***From research to engineering design,*** showing the practical results of some design projects in universities and polytechnics. The exhibition will be officially opened by the Rt Hon Kenneth Baker, Secretary of State for Education and Science, on 24 February 1987. Universities and polytechnics were invited to suggest suitable material for the exhibition, and the resulting wide selection of exhibits will cover such areas as marine technology, robotics, civil engineering, medical engineering, fibre optic communications and lasers.

The exhibition will be open to the public seven days a week from 25 February to 2 April inclusive.

Some new SERC publications

Council's annual report
Report of the Science and Engineering Research Council for the year 1985-86 was published in November 1986. Copies are available from HM Stationery Office bookshops in London, Manchester and Edinburgh price £5.00 or through institution libraries (ISSN 0261-7005; ISBN 0 901660 93 0).

Chemistry
The Chemistry Committee has published three documents: *Chemistry Committee report and statistical review 1986; Current grants in chemistry October 1986;* and *Achievements in chemistry,* a major review of the last ten years of SERC-funded chemical research. All are available from Dr P B Sharma, SERC Central Office, Swindon, ext 2496.

Molecular recognition
Molecular recognition: a Science Board initiative has been produced jointly by the Chemistry and Biological Sciences Committees and the Biotechnology Directorate. Copies are available from Mr A Buckley, SERC Central Office, Swindon, ext 2166.

Biotechnology
Copies of the *Directory of research in biotechnology, October 1986* are available from Mrs A Williams, SERC Central Office, Swindon, ext 2310.

Machines and power
Two reports from the Machines and Power Committee — *Reports on projects August 1986* and *Current grants August 1986* — are both available from Miss P Rogers, SERC Central Office, Swindon, ext 2117.

Design newsletter
Copies of the first issue of the *Newsletter* of the Engineering Design Initiative (see this page) are available from Mrs G Money, The Design Council, 28 Haymarket, London SW1Y 4SU.

The Alvey programme

The Alvey programme is now more than halfway through its official timescale; the current end date is 31 March 1989. Academic groups are involved in about 300 projects; almost 400 grants have been announced and a further 35 announcements are in preparation.

Details of the programme may be found in the *Alvey Programme Annual Report 1986* and its Poster Supplement, which can be obtained from the Institution of Electrical Engineers, PO Box 8, Southgate House, Stevenage, Herts SG1 1HQ, at a total cost of £30. Those already on the mailing list for Alvey News receive a copy free of charge.

SERC enquiry points

To make it easier to find the right person when you telephone our administrative offices in Swindon (or elsewhere), we are updating our list of key contact points. Except where otherwise stated, all extension numbers are at SERC Central Office, telephone Swindon (0793) 26222. A list of addresses appears on page 2.

ASTRONOMY AND PLANETARY SCIENCE DIVISION

Ground based studies	Dr A Game ext 2417
Research grants	J E Palmer ext 2359
PATT awards	Mrs A T Bratko ext 2198
Studentships and fellowships	N R Mayl ext 2267

BRITISH NATIONAL SPACE CENTRE

(CO: Central Office, Swindon; MT: Millbank Tower, London SW1 4QU; telephone 01-211 3000 or ext)

Space Science Programme Board

UK activities	Dr J H Price CO ext 2265
Research grants	J E Palmer CO ext 2359
International activities	Ms C A Iddon MT ext 7290
ESA fellowship scheme, Young Graduate Trainee scheme	D Peters CO ext 2219

Earth Observation Programme Board

UK activities	Dr D Williams MT ext 3510
International activities	Dr G Thomas MT ext 3957
Research grants	J E Palmer CO ext 2359

ENGINEERING DIVISION

Medical engineering	Miss C Rapier ext 2110
Materials	D Mullins ext 2238
Environment	Dr C Marsden ext 2353
Civil engineering	N L Williams ext 2155
Process engineering	Dr R K Burdett ext 2476
Fluid mechanics and thermodynamics	J W Reed ext 2478
Electrical engineering	C P Whitlock ext 2350
Applied mechanics	Miss P A Rogers ext 2117
Joint ESRC-SERC; studentships & fellowships	Miss M Wilson ext 2427
Information dissemination	Mrs J Broughton ext 2238
Design	A Spurway ext 2102

DIRECTORATES

ACME (including manufacturing processes)	Ms H Lennon ext 2106
Teaching Company	G Brooks ext 2151
Biotechnology	Mrs A Williams ext 2310

Information Technology

Alvey programme	Dr D Worsnip ext 2104
Control and instrumentation; communications	P Hicks ext 2401
Computing	M Hotchkiss ext 2260
Microelectronics facilities; solid state devices	Miss P C Davis ext 2161
Education and training	N Deighton ext 2428

The Marine Technology Directorate Ltd

(formerly SERC's Marine Technology Directorate) Mr I R Desai, 21 Little Smith Street, Westminster, London SW1P 3DH; telephone 01-222 7331.

NUCLEAR PHYSICS DIVISION

Nuclear structure; studentships & fellowships	Miss C Armstrong ext 2331
Particle physics	Dr A E A Rose ext 2278
CERN	M Bowthorpe ext 2271

SCIENCE DIVISION

Biological sciences and pharmacy	Dr P W H Fletcher ext 2136
Computing	A P Brown ext 2217
Mathematics	F Hemmings ext 2312
Neutron facilities	R G Tidmarsh ext 2212
Physics	J Farrow ext 2261
Science-based archaeology	Miss F Clouder ext 2361
Laser facility	S Clayton-Lucas ext 2213
Chemistry	Dr P Sharma ext 2496 R Coster ext 2263
Synchrotron radiation facility	Dr J O Wand ext 2113
Pharmacy	Dr G Ll Richards ext 2323
Molecular electronics	S D Ward ext 2173
Cooperative grants (Science)	Mrs V Nowlan ext 2412

FINANCE

Account queries	T A Trighton ext 2113

RESEARCH GRANTS

Most enquiries should be addressed to the appropriate subject committee

Terms and conditions; supply of forms	ext 2301

STUDENTSHIPS

Applications

Advanced course studentships	ext 2113
Research studentships	ext 2316
Studentships tenable abroad, including NATO	ext 2137
CASE and general enquiries	ext 2138

Current awards

For current studentships, give the switchboard the name of your institution.

FELLOWSHIPS

Postdoctoral (home, overseas and NATO), advanced and senior fellowships	ext 2172
Royal Society/SERC Industrial	ext 2352
Anglo-Australian Fellowships: J M Liptrott, Royal Observatory, Edinburgh	031-667 3321 ext 249
CERN	ext 2325
ESA	ext 2219

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

INTERNATIONAL COLLABORATION

(except NATO and SERC studentships and fellowships tenable overseas)	exts 2121, 2404 or 2253

CENTRAL COMPUTING

Dr B W Davies, Rutherford Appleton Laboratory, Didcot (0235) 21900, ext 5547

LINK	S D Ward ext 2173

SERC BULLETIN	ext 2120
PRESS ENQUIRIES	exts 2257, 2256

Impact engineering for safety

The Machines and Power Committee believes that a more coordinated approach is necessary in the areas it supports and is thus trying to formulate cohesive programmes of research in certain subjects, one of which is the behaviour of structures under impact conditions.

The term impact is defined by the International Standards Organisation as 'a single collision of one mass with a second mass'. Impact engineering is thus understood to embrace the analysis, design, construction and testing of structures and machines subjected to impacts, and of the applications of impact to the manufacture of objects.

There is a growing concern throughout industry about the need for improvements in safety standards, especially in the light of recent events within the nuclear industry. The need is therefore increasing for a coherent and coordinated research programme in the area of the behaviour of structures under impact.

Several research projects are already underway. Professor N Jones at Liverpool University, for example, was recently awarded a grant to study the dynamic plastic behaviour of structures.

Engineers and designers in several industries are encountering more and more problems in the economic design of structures which are subjected to large dynamic loads. This constantly leads to overdesigning, with structures often being made heavier than necessary in order to avoid failure due to potential impact hazards. Professor Jones's work should lead to the development of methods which will accurately predict the behaviour of structures subjected to large dynamic loads so that the structures will be more economically designed.

Related work is currently being undertaken by Professor G A O Davies's group at Imperial College of Science and Technology, although this concentrates on the behaviour of composite structures. It is proposed to investigate the stiffness, strength and failure mode of conical shells, constructed as geodetic frameworks, made from carbon composite elements. The immediate field of application is damage-tolerant helicopter fuselages and is jointly funded by the Ministry of Defence, but the work on composite behaviour carried out for this proposal should be relevant to other sectors of industry.

Studies on the behaviour of structures under impact conditions are important to a wide range of sectors, from the automotive and aerospace to the chemical and power generation industries.

Impacted cylindrical tubes, showing how different metals behave under impact.

A coordinated programme of research within this important area should eliminate the problems of overdesign through ignorance, thus leading to considerable savings to industry in economic terms, and, more importantly help improve safety within these industries.

For further information, contact Miss Philippa Rogers, SERC Central Office, Swindon, ext 2117.

A diesel train travelling at 100 mph crashes into a nuclear fuel flask, in a demonstration by CEGB to prove the immense strength of the containers: the diesel was destroyed; the flask was unscathed. *(Photo: CEGB)*