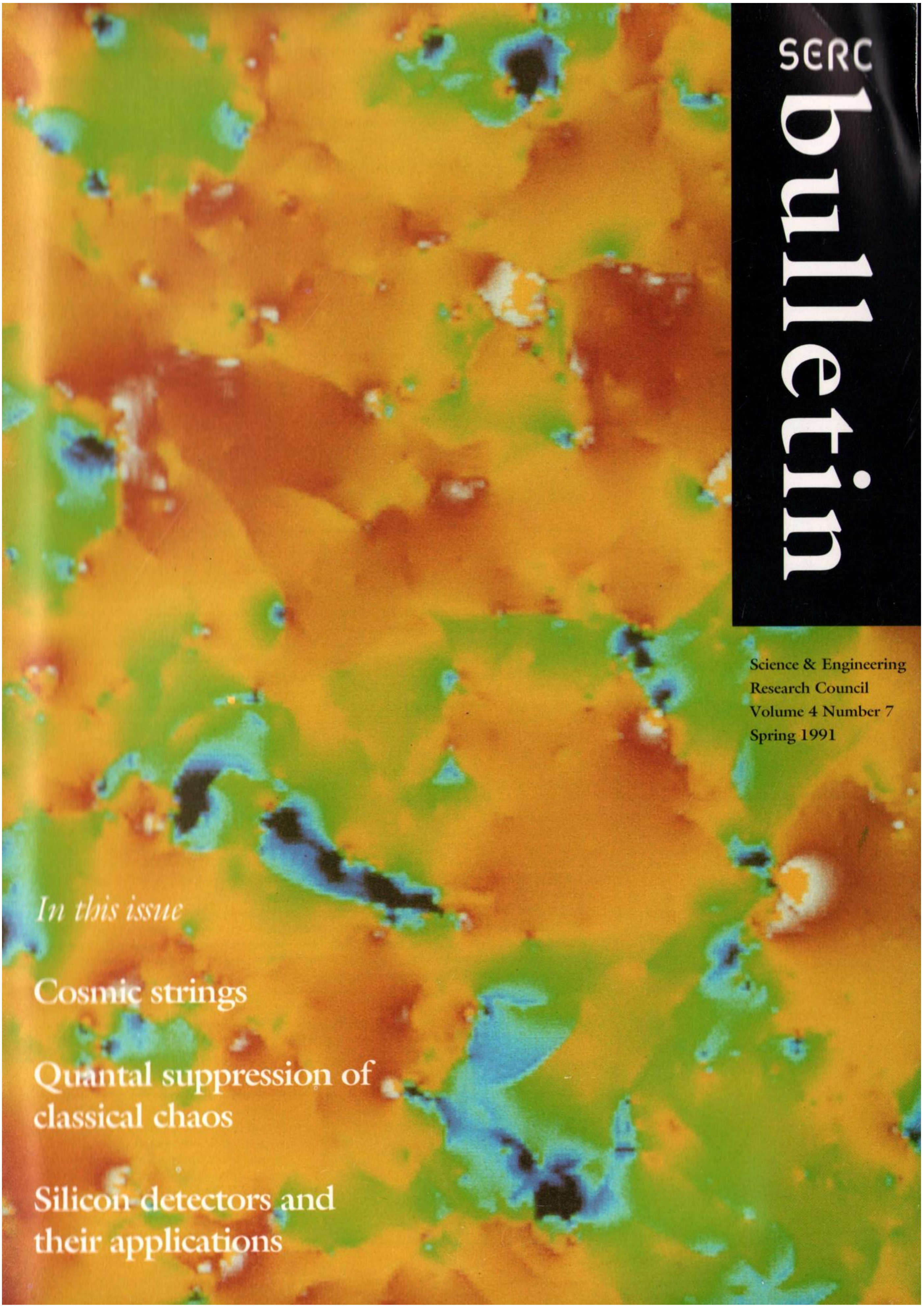

SERC bulletin

Science & Engineering Research Council
Volume 4 Number 7
Spring 1991

In this issue

Cosmic strings

Quantal suppression of classical chaos

Silicon detectors and their applications

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.

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SERC *Annual Report* (available from PRU, SERC Swindon Office) 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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Sir Ben Lockspeiser KCB, FEng, FRS (1891–1990)

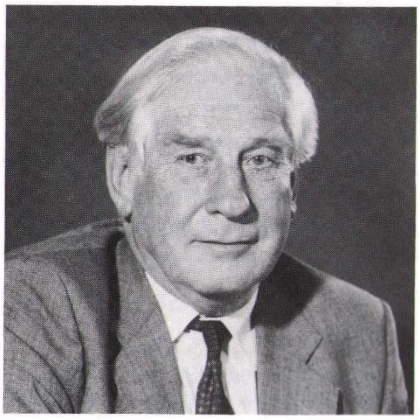
Sir Ben Lockspeiser, who died at the age of 99 on 18 October 1990, was Permanent Secretary of SERC's predecessor the Department of Scientific and Industrial Research from 1949 until his retirement in 1955. An outstanding scientist and administrator, he spent 17 years in aeronautical research at the Royal Aircraft Establishment, Farnborough, then progressed through Assistant Director and Director of Scientific Research at the Air Ministry to Chief Scientist at the Ministry of Supply in 1946. Thus, when he succeeded Sir Edward Appleton at the DSIR in 1949, he had already had ten years of experience in government administration, which he used to great effect in surmounting innumerable difficulties. In 1955 he became President of the newly formed European Organisation for Nuclear Research (CERN) for two years.

In this issue

Front cover picture

The effect of strings on the Universe. An example of the microwave anisotropy pattern produced by a network of cosmic string. (Photo: Bennett, Lawrence Livermore National Laboratory; Bouchet, Institut d'Astrophysique de Paris; and Stebbins, Canadian Institute for Theoretical Astrophysics). See page 8.

Shortfall in SERC's funding



Sir Mark Richmond

Statement from the Chairman Sir Mark Richmond

Science seems to hit the headlines in a big way only when there is a crisis over its funding. The media have revealed much of the trauma that SERC and its community has been through over the past months in the process of making almost impossible decisions on cuts in its research programme. I hope that some good may come from the sustained focus on the excellent science that SERC supports.

I very much regret the need for the cutbacks announced below, some of which may have an impact on work described in this issue of *SERC Bulletin*. They were forced on us by mounting pressure on our costs aggravated by a very poor Public Expenditure Survey settlement for the Science Budget this year coupled with the corrosive effects of inflation.

I fully appreciate that, as a result, much excellent work has been jeopardised but I believe SERC has charted a viable way forward for the next five years. It is important to remember that the great majority of our programme of research and training continues to thrive.

At its February meeting the Council announced measures to combat the shortfall in its funding for 1991-92 and the effects of this on subsequent financial years.

The January announcement of the science vote gave SERC £450 million for 1991-92, an increase of £12 million — 3% — over the previous financial year.

The measures decided by the Council to match its programmes to its allocation were:

Astronomy and Planetary Science

The funds of the Board would cover many of its existing projects including:

- SOHO/Cluster, the first cornerstone mission of the European Space Agency
- Much of the existing ground-based programme including a share of the 8-metre optical telescope in two years' time.

At present there were insufficient funds for the Polar Cap Radar, the Gravitational Wave Observatory, the Lyman/FUSE missions and a full portfolio of Earth observation instruments for the Polar Platforms. No decision could yet be made on Spectrum X.

Engineering Board

Although funds would enable the Engineering Board to maintain much of its present programme of work including support for grants, studentships and education and training, this allocation would still require sharp cutbacks in a number of areas, notably in:

- information technology
- the application of computing in manufacturing engineering
- engineering design
- support provided by Rutherford Appleton Laboratory (RAL) for engineering applications of computing in universities and polytechnics.

The Board intends to expand its support for clean technology.

Science Board

The level of funding allocated to the Science Board could not sustain its existing programme. In particular it would be unable to afford to support two major neutron facilities at the Institut Laue-Langevin in Grenoble and Isis at RAL at the present level. To help the Council reach decisions in this area a study — to report in October 1991 — would be carried out to assess the UK's need for neutrons over the coming years and the most effective way of providing them. Until a decision on the provision of neutrons could be reached, the Board's expenditure on grants and student awards would have to be reduced.

In addition the Council would be unable to pursue proposals for a European Laser Facility within the next few years.

Nuclear Physics Board

The Council was committed to pay the UK share of the CERN subscription and the associated UK research on particle physics. For the Nuclear Physics Board to remain within its budget, it would have to reduce very significantly its support for nuclear structure physics. To achieve this the Council would have to make plans for the possible closure of the Nuclear Structure Facility at the Daresbury Laboratory. Commenting on this, Sir Mark Richmond said: "This is a leading facility for this type of research in the world which we had hoped would keep the UK in the forefront of nuclear structure science for some years ahead. I greatly regret the shadow cast over this facility, its staff and the community it supports. The Council will look urgently for ways to run the facility through 1991 and 1992, so we can honour the first stage of the UK-French Agreement to develop and run the EUROGAM detector array."

To help the Council in its further consideration of these issues, a study will be set up to assess the importance of the science in the context of Council work as a whole.

Research grants freeze lifted

The 'freeze' on some research grants was lifted by the end of February 1991. In the financial year 1991-92, the Council expects to be able to fund only up to half the number of new grants compared with recent years. The Council greatly regrets the impact of this on universities and polytechnics. The Council expects the proportion to improve from 1992-93 onwards.

Studentships

£4.25 million has been earmarked in each of the planning years to support an increase of £400 in the studentship stipend.

Computing

The Council has had to reduce support for central computing facilities in real terms. Priority has been given to protecting supercomputing facilities and networking services provided by SERC for the academic community.

Council commentary October 1990 – February 1991

Lower limit to grant applications abolished

The abolition of the lower limit for SERC grant applications of £25,000 was agreed by the Council in October. The limit, originally intended mainly to control demand for small items which should be available in a 'well found laboratory', had not produced any identifiable benefit according to an independent study on SERC's grant system, commissioned by the Department of Education and Science.

Visiting committees report

Two 'visiting committees', set up to provide an overall independent monitoring of the management and organisation of SERC establishments, reported to the Council in October 1990. The committees reviewed the Rutherford Appleton Laboratory, Daresbury Laboratory and SERC's Swindon Office. A number of constructive proposals on management and other aspects were made and implementation agreed. The Council also reviewed the future of the committees and it was agreed that they played a valuable role and should continue.

Telescope partners agreed

In November, despite the need to delay the 8-metre telescope project (see page 3), the Council agreed in principle to associate with the USA and Canada in their proposed project to build one telescope on Mauna Kea, Hawaii and another in Chile. The project would offer British astronomers access to the highest quality infrared and optical telescopes in both northern and southern hemispheres by the end of the century.

Instant Studentship Scheme ended

The Instant Studentship Scheme, introduced in 1965 to facilitate the return of able scientists and technologists in industry to higher education institutes for further training, was terminated by the Council in December. A review has shown that most such training can be accommodated within the Council's normal schemes for postgraduate students. Given the Council's financial position, the scheme is not a priority use of scarce resources. A saving of about £0.8 million in 1991-92 will result from ending the scheme.

International subscriptions

International subscriptions from SERC funds for 1991 were approved by the Council in December as follows (at current exchange rates):

- European Space Agency: up to £24.57 million
- Institut Laue-Langevin: up to £9.68 million
- European Synchrotron Radiation Facility: up to £6.3 million
- European Science Foundation: £0.25 million

Corporate plan

At its February meeting, the Council agreed to publish its third corporate plan this autumn.

PhD submission rates

Sanctions threshold to increase in 1993

At its February meeting, the Council decided to raise the level of PhD submission rates below which mandatory sanctions are applied from 35% to 45% . From 1993, Departments that fail to achieve this level may be sanctioned.

Telescope wins top engineering award

The prestigious Fellowship of Engineering MacRobert Award for 1990, made for innovation in engineering, was won by a team of five engineers and scientists from SERC's Rutherford Appleton Laboratory, Cambridge University and the Netherlands, who designed and engineered the James Clerk Maxwell Telescope in Hawaii. The award includes a gold medal and £25,000.

The telescope, now run by SERC's Royal Observatory, Edinburgh, is the most sensitive radio telescope of its kind in the world. Among the key design features recognised by the award were:

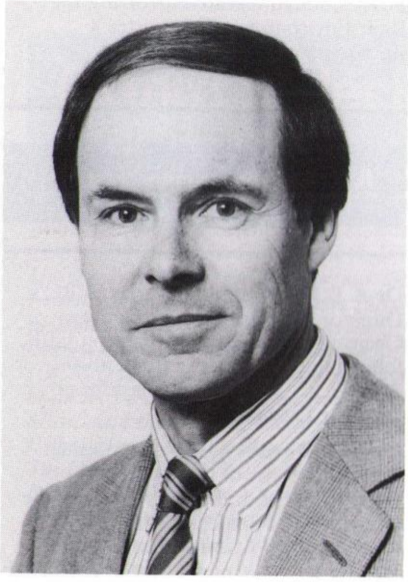
- the woven PTFE blind which allows 95% of the sub-millimetre part of the spectrum to pass but no more than 20% of solar radiation. The blind allows the telescope to operate 24 hours a day and it has worked successfully in winds up to 80 miles an hour;
- the very accurate lightweight surface panels, 276 of which make up the primary reflector and the computer-controlled panel adjusters so keeping the accuracy of the surface of the dish to within half the thickness of a human hair;
- the reflector support structure which keeps the dish to a paraboloidal shape as its elevation changes.

The team comprised: Dr Ron Newport (Project Leader and now Head, SERC's Science Division), Dr Jim Hall and Brian Edwards (RAL), Professor Richard Hills (Cambridge University) and Dr Jean Louis Casse of NWO (the Netherlands Organisation for Scientific Research).

New Council members

As reported in the last issue of the *SERC Bulletin* (Volume 4 No 7, Autumn 1990), five new members were appointed to the Council last autumn. They were: Professor R E Hester, Dr N W Horne, Professor J S Mason, Dr J O Thomas and Professor D J Wallace, who has also been appointed Chairman of the Science Board in succession to Professor Brian Fender. Dr Horne has subsequently resigned.

Professor Ron Hester is Professor of Chemistry at York University. He was a member of SERC's Science Board and Chairman of the Chemistry Committee from 1988 to 1991 and member, then Chairman, of the Physical Chemistry Subcommittee. Ron Hester joined York University in 1965 as a Lecturer, after several years at Cornell University, USA. He was promoted through Senior Lecturer and Reader to Professor in 1983. Recent research work has concerned the application of vibrational spectroscopic methods to the study of problems in photochemistry, electrochemistry, biochemistry and generally in surface and thin film studies. He is currently involved in collaborative work with Rutherford Appleton Laboratory groups at the Central Laser Facility and the neutron spallation source Isis.



Professor R E Hester

Professor Stan Mason is Principal of Glasgow Polytechnic. He began his career at the coalface and graduated in mining engineering from Nottingham University. After teaching and serving in the Royal Navy as an engineer, he was appointed Principal Lecturer in mechanical engineering and Head of the Fluid Mechanics Division at Liverpool Polytechnic in 1966. In 1973 he joined Thames Polytechnic as Head of the School of Mechanical Engineering, became Head of the new School of Engineering and Dean of the Faculty of Technology in 1985 and, in 1987, Deputy Director of Glasgow College of Technology (now Polytechnic), being appointed Principal in 1989. He has won several awards for his work on the handling of bulk solids. Professor Mason is a member of the LINK steering group.

Professor J S Mason

Dr Jean Thomas FRS is Reader in Biochemistry of Macromolecules at Cambridge University. After gaining her PhD in Organic Chemistry from the University of Wales (University College Swansea) and two years of postdoctoral research at the Laboratory of Molecular Biology in Cambridge, she became University Demonstrator in Biochemistry at Cambridge, Lecturer in 1973 and was promoted to Reader in 1987. She has been a member of SERC's Biochemistry and Biophysics Subcommittee (1983-86) and Management Panel for the Molecular Recognition Initiative (1986-89). Her research interests centre on protein-DNA interactions in chromosome structure and function, using biophysics, chemical and molecular biological approaches.

Dr J O Thomas

Professor David Wallace FRS is Tait Professor of Mathematical Physics at Edinburgh University and Director of the Edinburgh Parallel Computing Centre. He spent two years at Princeton University, USA, after gaining his PhD from Edinburgh University. In 1972 he was appointed Lecturer (later promoted to Reader) in the Physics Department at Southampton University, returning to Edinburgh as Tait Professor in 1979. Professor Wallace has been a member of SERC's Science Board (1987-90), its Physics Committee (of which he was also Chairman), the Solid State and Low Temperature Physics Subcommittee and the Science Board Computing Committee. His work is in the field of theoretical and computational physics with particular interest in lattice guage theory and critical phenomena and neural network models.

Professor D J Wallace

Mainz photon-tagger

The inauguration of a photon-tagging spectrometer at the University of Mainz in January marked the completion of a major collaborative project between the Universities of Edinburgh, Glasgow and Mainz. The £1 million capital funding of the spectrometer was provided by a grant to Glasgow University by SERC's Nuclear Physics Board.

The photon-tagger is situated on the newly completed 850 MeV microtron accelerator at Mainz. It will enable nuclear physicists to probe the atomic nucleus with high-energy X-rays or photons to determine some of the many processes that occur within them.

The technique was pioneered by the Glasgow and Edinburgh groups using equipment on a lower energy accelerator at Mainz which was closed in 1987.

Following the outstanding success of this earlier work it is hoped that the new, higher energy accelerator and photon-tagging system will enable information to be obtained on the structure and interactions of the particles within the atomic nucleus with previously unachievable precision.

MTD Ltd, the next three years

Sir Mark Richmond (left), Chairman of SERC, and Admiral Sir Lindsay Bryson, Chairman of the Marine Technology Directorate Ltd, signed a new three-year agreement between SERC and MTD Ltd, in October 1990. Under the agreement, SERC makes payments to MTD Ltd for operating costs and for extramural costs — services in support of SERC-funded research in marine technology.

Congratulations to . . .

. . . **Professor Arnold Wolfendale FRS** (member of SERC Council and Chairman of the Astronomy and Planetary Science Board) on his appointment as Astronomer Royal, succeeding Professor Sir Francis Graham Smith.

. . . **Professor Sir William Mitchell CBE, FRS** (former Chairman of SERC) on his election to the Presidency of the CERN Council.

. . . **Professor Peter Twin** (Chairman of the Nuclear Structure Committee and formerly Head of the Nuclear Structure Facility at Daresbury Laboratory) on winning both the John Price Wetherill Medal of the Franklin Institute and the Tom W Bonner Prize of the American Physical Society, for his work on superdeformation in nuclei and Compton-suppression germanium detector arrays.

. . . **Dr W M Rainforth** on winning the 1990 Tribology Bronze Medal of the Institution of Mechanical Engineers for his work in the field of wear between ceramics and metals, done while a SERC 'CASE' student in the Materials Department at Leeds University.

. . . **Peter Little** (Research Assistant in the Pavement Research Group, Nottingham University) on winning the Mike Hardy Award of the Institution of Highways and Transportation, for SERC-funded research involving the Built Environment Committee's Bothkennar Soft Clay Site.

Appointments

Dr A E Hughes takes over as SERC's Director Programmes and Deputy Chairman from Mr A J Egginton CBE, following the latter's retirement on 31 March. Tony Hughes is currently Director Laboratories.

Dr P G Murdin has been appointed Acting Director of the Royal Observatory, Edinburgh, following the resignation of Professor Malcolm Longair. Paul Murdin was formerly Deputy Director of the Royal Greenwich Observatory.

SERC – AFRC Clean Technology Unit

The Clean Technology Unit set up jointly by SERC and the Agricultural and Food Research Council (AFRC) is now operational. SERC's Engineering Board is earmarking substantial funds for clean technology, building up to £4.5 million a year in 1993-4. The corresponding baseline of expenditure by the AFRC is £1 million a year. Both Councils aim to increase expenditure beyond these baselines, if the volume of excellent research proposals justifies it.

SERC has already backed an initial portfolio of 40 projects ranging from fundamental work on the chemistry of combustion to the use of lignite in a novel separation process that could for example be used to remove organic pollutants from factory effluent.

The Clean Technology Unit is supported by a Management Committee under the chairmanship of Professor Roland Clift (Surrey University). In October 1990 AFRC and SERC jointly published a consultative document *Clean Technology* about their plans. The Unit is currently evaluating comments on that document and defining the strategy for the programme. The main elements are likely to be:

- clusters of research grants aimed at announced research targets (see below);
- generic research, for example on highly selective catalysts;
- small grants for testing unconventional ideas;
- special attention to research aimed at new inherently clean processes, as opposed to end-of-pipe fixes.

Studies are in progress to enable the Management Committee to choose its first major research targets. The current shortlist is:

- biosynthesis of 'effect' chemicals and alternatives to bulk chemicals;
- clean processes based on photosynthesis to derive new chemical feedstocks or fuels;
- concentration and disposal of dilute waste;
- the redesign of farming as an engineering process;
- the 'civilised city';
- systematic assessment of environmental effects (to be pursued in consultation with the Economic and Social Research Council).

The present baseline budgets will probably allow a start on four of these targets; Nicholas Lawrence, Director of the Unit, plans to announce which in mid-1991. The Unit will arrange regional meetings so that the relevant research communities can discuss the targets and get together to form partnerships to prepare joint or complementary grant applications.

The Unit particularly encourages intending applicants to send, in the first place, a short outline of their proposals. It will then give advice on whether and how to frame a full proposal, and ensure that full proposals get a sympathetic hearing from the appropriate part of SERC's and AFRC's peer review systems. All research supported by the Unit will have to be of high alpha quality as judged by peer review, and the Unit's budget will be used to 'gear' the 'clean' grants that subject committees are already approving.

Dr Lawrence is keen to hear from people who need a small short-term grant to try out an unconventional idea which could lead to a new clean technology — "but please," he says, "no more perpetual motion machines!"

Contacts: **Nicholas Lawrence** or **Anita Longley** at SERC Swindon Office; telephone (0793) 411122; or **Malcolm Anderson** at AFRC; telephone (0793) 413200.

Oxford Molecular Sciences Centre tour

Junior Minister for Science Alan Howarth CBE, MP (left in picture) visited Oxford University in December 1990 to tour the Interdisciplinary Research Centre (IRC) in Molecular Sciences. Known as the Oxford Centre for Molecular Sciences (OCMS) this was one of the first IRCs to begin in 1988 with joint support from SERC and the Medical Research Council to the value of £7.2 million over six years. The Director of the IRC is Professor Jack Baldwin FRS who, with project leaders Professor Louise Johnson, Dr Chris Dobson and Dr Ian Campbell, comprise the senior management team.

The picture shows Dr K Harlos (right) explaining to Mr Howarth the principle of the 'sitting drop' method using an invention by Dr Harlos called a microbridge to facilitate protein crystallisation on a very small scale.

Cosmic strings

A particle physics solution to the large-scale structure of the Universe

During the past decade there has been a developing interplay between the disciplines of elementary particle physics and cosmology. The former has had great success in demonstrating the unification of the weak and electromagnetic forces, at energies just above 250 x 10^9 electron volts (GeV) or 10^{16} degrees Kelvin. The so called 'standard model' seems to describe accurately the interactions of quarks and leptons at and below these energies, as demonstrated daily in the Large Electron Positron (LEP) collider at CERN. However the frontiers of particle physics also involve energies much greater than the 10^3 GeV available in terrestrial accelerators. Theories which attempt to unify the strong and electroweak forces (the Grand Unified Theories — GUT) require unification energies of around 10^{15} GeV. For this reason many particle physicists have turned to the early Universe where these sorts of energies were believed to exist just 10^{-35} seconds after the Big Bang. The Universe is a unique, exciting laboratory in which we can investigate physics at extremely high energies and very short distances. Ed Copeland of Sussex University, who is supported by the Nuclear Physics Board, discusses the link between cosmology and elementary particle physics.

For cosmology, the hot Big Bang model — the 'standard model of cosmology' — seems to provide an accurate account of the history of the Universe from about 10^{-2} seconds after the bang when the temperature was 10 MeV (million eV) until today, 10 to 20 billion years later, and a temperature of 2.7 K (10^{-10} MeV). Extending our knowledge of the Universe to earlier times and higher temperatures requires knowledge about the fundamental particles (quarks, leptons) and their interactions at very high energies — thus cosmology and elementary particle physics are linked together.

The hot Big Bang model accounts for the expansion of the Universe today, the 2.7K cosmic microwave background radiation, and through primordial nucleosynthesis, the abundances of the light elements helium, deuterium, and lithium. The microwave background is a fossil record of the Universe from the time when matter and radiation decoupled (100,000 years after the bang). Its incredible isotropy (we observe the same temperature in all directions to better than one part in 10,000) and pure blackbody spectrum in all wavelengths are consistent with the standard cosmological picture. Our Universe is very smooth, homogeneous and isotropic on the scales of our observable horizon.

Therein lies the problem facing us. Each evening, weather permitting, we can look up to the night sky, and see *no* evidence for isotropy and uniformity. Rather we see lots of structure. If the Universe started off as smooth as is indicated from the microwave background, what were the seeds that led to all this structure? Actually the Universe is full of interesting structure on scales much larger than we can see with the naked eye. Recently astronomers have been devoting a great deal of time and effort to mapping the large-scale structure, and their initial results are fascinating. They indicate that galaxies and clusters of galaxies appear to be located on the apparent surface of huge bubbles nested together. Inside the bubbles are enormous voids, up to 150 million light years across, empty of all but a few galaxies. Galaxies form at the intersections of these bubbles, along filaments 200-300 million light years in length. On these scales the Universe is anything but smooth. Many cosmologists believe that there has not been enough time for gravity alone to push galaxies into these special positions. The bubbly structures are an imprint of processes that occurred at the earliest moments of creation, some 10^{-35} seconds after the Big Bang. It is in this era that the candidate seeds for the observed structure could be born; cosmic strings provide one such candidate.

The unification of the forces of nature is mediated through phase transitions, during which a particular symmetry, which previously unified the forces at a high temperature, is broken as the temperature falls below a critical value, leaving behind distinct separate forces. Experimentally this is seen in the weak and electromagnetic forces, around 250 GeV. Above this energy they are described together as one electroweak force, whereas at home (well below this energy) we do not associate turning on an electric light bulb (electromagnetic effect) with the radioactive decay of a nucleus of an atom (weak force). The same principle applies at the GUT scale, 10^{15}GeV. Above this energy, the strong and electroweak forces are described as one, cooling below the energy, a phase transition occurs as the symmetry unifying the forces is broken, and we are left with two distinct forces.

In 1976, Professor Tom Kibble of Imperial College, London, realised that there are important cosmological consequences from these GUT transitions. One comes from the fact that the transition would probably be 'flawed'. As the Universe expands and cools, the phase transition could leave regions of space trapped in the 'old' high energy phase (where the forces are still unified), surrounded by the 'new' low energy or broken phase. Such 'defects' are regularly seen at much lower energies in condensed matter physics. They can take many forms; for example they could be pointlike (monopoles), sheetlike (domain walls) or one dimensional string like objects, hence cosmic strings. Monopoles and domain walls are

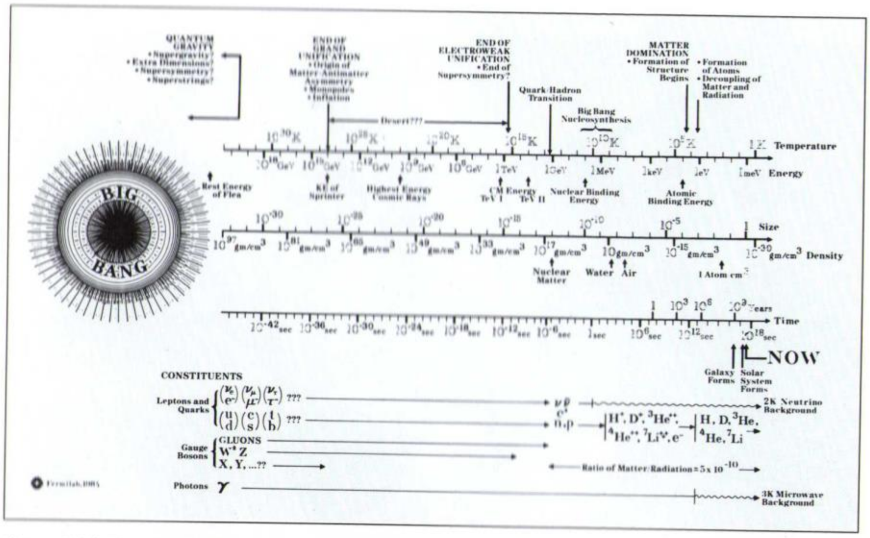


Figure 1: The interface of elementary particle physics and cosmology is shown in this brief history of the Universe.

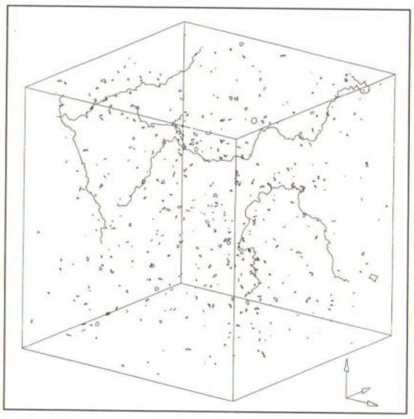


Figure 2: Portion of a numerical box showing the evolved cosmic string system. The horizon at this time is approximately 3.5 times the box sidelength. Note the large number of small loops on scales much less than the horizon, and the few infinite strings stretching right across the box. (Picture Shellard, Cambridge; and Allen, Wisconsin).

potential problems for cosmology, but cosmic strings appear to be ideal candidates to act as structure forming seeds. They are extremely thin, about 10^{-29}cm (the radius of an atomic nucleus is around 10^{-13}cm), but possess an immense tension (the 'old' phase of high energy still exists there) of 10^{36} Newtons.

Numerical and analytical calculations indicate that at birth the strings emerge as a tangled mesh; around 80% of the network is in long 'infinite' strings winding their way across the visible Universe and the rest is in closed loops (for topological reasons they must be either infinite or closed). As the Universe expands, the string network begins to evolve, the long strings moving at close to the speed of light intersect each other as they stretch out, chopping off loops as they do so. Some of the loops chop themselves up further, others reconnect on to the long strings, but a picture emerges where the initial high density of infinite string diminishes as more and more loops are formed. Eventually a 'scaling solution' is reached where the density of long strings is a constant fraction (around 10^{-5}) of the total energy density of the Universe.

The evolution equations are nonlinear and difficult to solve analytically, so most of the work is numerical with three different groups independently running codes. The simulations differ on the exact evolution of the loops of string. One group find they also reach a scaling solution as with the long strings, but two groups appear not to reach this point. Because of the large amount of small-scale structure on the long strings, created each time they intercommute, they tend to find that most of their loops are close to the smallest possible allowed size. Although this difference needs to be accounted for, most of the string 'action' for galaxies comes from the long strings, an area where there is general agreement between the groups. The strings lose energy primarily through gravitational radiation. As they oscillate rapidly close to the speed of light, the loops radiate, shrink and eventually disappear. The detection (or lack of detection) of such radiation could well one day confirm or rule out the whole scenario.

Such is the tension of the long strings, they distort the spacetime in which they live, causing a flat spacetime to become conical, the string passing through the vertex of the cone.

The effect of this distortion is to cause particles moving by the string to be drawn in, effectively attracted behind it into wakes. All the long strings passing through a sea of particles will then leave wakes in their trail. It is in these regions, where there is now an excess of matter, that the conditions are established for the formation of large-scale structure, as the massive particles become gravitationally bound to one another. As matter, both luminous and dark, is attracted into these regions, they leave behind empty spaces. The important question is whether this scenario can produce enough density perturbations to account for the observed distribution of galaxies, clusters and voids, as well as the bubbly nature of the distribution. This is a complicated issue, and groups are currently running large many-body codes to investigate these questions. It appears that the answer could depend critically on the scaling density of long strings. If it is too high then the strings are close together and the voids produced are not large enough.

Models which rely on physics from 10^{-35} seconds after the Big Bang are of little use if they do not leave some observationally verifiable signature. Fortunately cosmic strings leave some unique calling cards. A string situated between Earth and a faraway galaxy would bend the flow of light passing either side of it from the galaxy, due to the conical nature of the spacetime around the string. The result is that we would see two images of the galaxy instead of just one, an effect known as gravitational lensing.

There are a number of potential lensed quasars, but also many candidate lensing objects, not just strings. However a chain of galaxy pairs across the sky would be a strong signature of a string, indicating the lens was long and thin, not pointlike. Preliminary results showing the lensing of seven objects in a small region of the Universe have recently been published. A string? Time will tell.

Perhaps the most convincing evidence for their existence would be from the unique signature they would leave in the Universe's microwave background (see front cover picture). This background, the residual glow of the Big Bang itself,

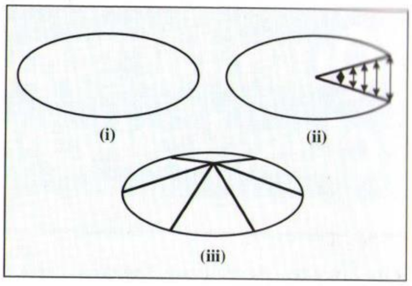


Figure 3: The conical space around a straight string: (i) Section of Euclidean space; (ii) With string present, effect is to cut out a wedge of small angular size from Euclidean space and identify the exposed surfaces. The string passes through the vertex; (iii) Exagerated perspective of conical space around a straight string passing through the vertex.

is extremely uniform, but a string moving rapidly through it would heat up the microwave slightly in the wake of the string, and cool it in front of the string. The microwave background would appear roughly 10^{-4} of a degree hotter on one side of the string than on the other. Maps of the microwave background would show this temperature jump as a line tracing the position and shape of the otherwise invisible string: a truly unique signature. It says a great deal for the expertise in this area of detection that such a small jump may soon be detectable, so cosmic strings should soon be confirmed or ruled out.

Particle physics is having a dramatic and exciting effect on cosmology. Many astronomers are trying to get valued telescope time to search for the exotic cosmic strings. There are other topologically inspired candidates that have not been mentioned here, but are causing great interest as possible seeds for large-scale structure. They include superconducting cosmic strings and global textures. It is a thrilling thought that if cosmic strings are discovered, it will be possibly the best evidence to date for Grand Unified Theories, and it will have come from observing the Universe, not from the particle accelerators.

Dr E J Copeland
Physics and Astronomy Division
Sussex University

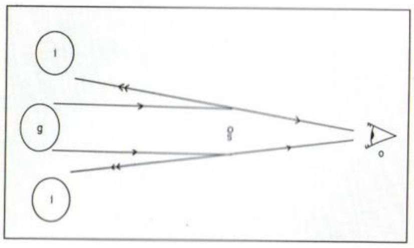


Figure 4: Lensing by cosmic strings. Light rays emitted by a distant quasar (g) intersect behind the string (s), (which is pointing into the paper), and the observer (o) sees two images (i) of the same quasar.

Quantal suppression of classical chaos

The laws for describing the dynamics of microscopic systems were discovered about 60 or so years ago, and those for macroscopic systems were established by Newton 360 years before that. However, the limiting relation between the two sets of laws is not well understood and has been attracting increasing attention in recent years. Derek Richards of the Open University explores aspects of this difficult but interesting area.

Traditional atomic and molecular physics deals mainly with systems in which relatively few quantal states dominate the dynamics; laboratory atoms or molecules are normally near the ground electronic state and electrons are tightly bound to the nucleus by strong electric fields having magnitudes which are sizable fractions of an atomic unit; far larger than any available laboratory field. Moreover, the spectra are relatively simple and well structured, ideally suited to the classification schemes of conventional spectroscopy which are based on perturbation theory. As the quantum numbers increase the density of states increases, as depicted in figure 1; the energy separating individual levels decreases and they become more susceptible to small perturbations.

The use of lasers in atomic physics enables researchers to probe systems with very high quantum numbers so presenting theoreticians with new problems for which conventional techniques are of limited use. The spectra of high lying molecular states have so many lines that conventional classification schemes cannot be used; for instance 27,000 lines of H_3^+ have been observed in the energy range 850-1100 cm^{-1}. For highly excited states the binding energies and energy level separations are so small that conventional laboratory fields can be used to perturb the atomic motion significantly. Both these features mean that perturbation theories are invalid, or of limited utility.

For such highly excited systems the numerical solution of Schrödinger's equation — not easy even for moderately complex atomic processes with small quantum numbers — is practically impossible even on large computers. But for such large quantum numbers the correspondence principle can usually be used: crudely, this states that as the quantum numbers increase, quantal effects become insignificant and so the laws of Newton provide a good approximation to the motion. As these can be solved relatively easily on modern computers, the labour needed to solve Schrödinger's equation ought to be unnecessary. Nature, however, is not so kind: Newton's equations are nonlinear and for many highly excited systems produce chaotic motion for which there is no simple quantal equivalent. The unperturbed hydrogen atom of figure 1 is an exception.

A simple common analogy of this problem is in the vibrations of a drum. The low lying states of atoms are equivalent to the low harmonics of a regularly shaped drum — a circle or rectangle for instance — for which the frequency spectrum is ordered and comprises distinct harmonics. The high lying states are equivalent to the high harmonics of a drum with an irregularly shaped boundary and the frequency spectrum now contains many spikes with no simple discernible pattern.

The fact that new experiments on highly excited hydrogen have coincided with the growing awareness and understanding of chaotic motion in nonlinear systems has emphasised the fact that we do not properly understand the subtle relations between the solutions of Schrödinger's and Newton's equations as the relevant quantum numbers become large. In other words, how the behaviour of a system becomes classical in the limit of large quantum numbers, and the circumstances under which classical behaviour prevails. Much of our knowledge of this limit comes from computer studies on model systems, but there are a few examples on which both experiments and theory can be performed. Two of these involve excited hydrogen atoms — with principal quantum numbers between 20 and 100 — in relatively strong electromagnetic fields. In one case (Welge at Bielefeld) magnetic fields of about 6 tesla are used to produce a non-integrable conservative system.

In the second case (Koch at State University of New York, and Bayfield at Pittsburgh), which we consider in more detail here, the highly excited hydrogen atom is perturbed by a periodic electric field of strength comparable to the binding Coulomb field and microwave frequency Ω comparable to the electron orbital frequency. Typically the perturbation acts for several hundred field periods and the experiments measure the proportion of atoms ionised. For this system Newton's laws give relatively simple equations which can be numerically solved quite easily. When this was done there were two surprises. First, all orbits which ionise are unstable while en route to the continuum. Second, for a significant range of frequencies the classical and experimental ionisation probabilities agree remarkably well.

An example of this agreement is shown in figure 2, where we show the strength of the field needed to ionise 10% of the atoms entering the field. In order to understand this figure it is helpful to imagine a classical atom in which the electron orbits the nucleus in a Kepler ellipse with frequency $\omega(n)$, which depends upon the initial principal quantum number n as $\omega(n) \propto n^{-3}$: in classical dynamics the two time-scales of the problem are defined by Ω and $\omega(n)$, so the important ratio is the scaled frequency $\Omega/\omega(n) \propto n^3\Omega$. We plot the 10% threshold field against this scaled frequency; in a typical experiment Ω is fixed, Ω = 9.92 GHz for the data of figure 2 and 36.2 GHz for figure 3, and specific values of n chosen in the range $32 \le n \le 90$ to give the discrete set of solid dots: the classical 10% thresholds are depicted by the solid line. In the scaled frequency range shown the agreement is quite remarkable; the main discrepancies are at the resonance ratios $\Omega/\omega(n)$ = 1/3, 2/5 etc, where we see local maxima suggesting that the system is locally more stable near resonances and that the real system is less sensitive to the field than the classical system. Here the disagreement has been traced to the

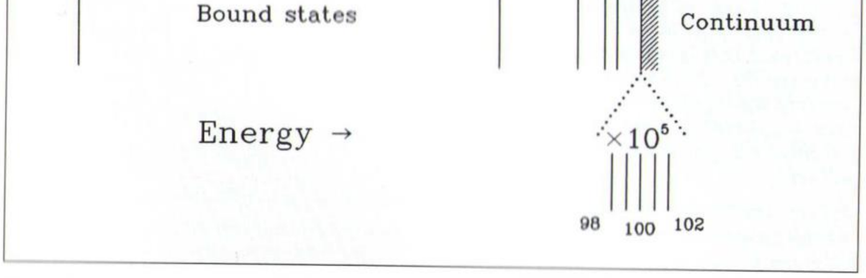


Figure 1: Energy levels of low- and high-states of atomic hydrogen, showing the increasing density of states with increasing principal quantum number, n.

strange fact that wave effects emphasise the unstable orbits in the vicinity of the resonances by producing stable local maxima of the wave function centred on the unstable classical orbit. Curiously these important frequency ratios are the positions of the Kirkwood gaps in the asteroid belt — that is, the relatively empty, narrow bands around those radii at which the orbital frequencies are in approximate resonance with Jupiter's period. But in that case the resonant motion leads to less stable motion, which is why there are gaps. The Newtonian equations of motion of these two systems are sufficiently similar for the dynamics to emphasise the same resonances, but the differing time-scales (hundreds of periods for the atomic system and hundreds of thousands of periods for the asteroids), relative force sizes and quantal effects lead to different consequences.

To complicate matters, when the frequency ratio $\Omega/\omega(n)>1.5$, systematic differences between the experimental and the classical thresholds become apparent as shown in figure 3.

For these higher frequencies, quantal wave effects add coherently over long times and make the system more stable against the perturbation of the field. Classical paths add incoherently to produce chaotic motion; the simplest analogy being the two-slits experiment in which the addition of classical probabilities produces quite different effects from the addition of quantal amplitudes. The result being that, even for the very large quantum numbers of these experiments $n \sim 90$, the classical equations of motion provide an inaccurate description of the motion. Normally it is possible to use classical paths to provide good approximations to wave motion for $n>10$, just as high-frequency wave motion may be approximated by rays.

The root cause of this problem is the periodicity of the driving force; wave effects make the quantal system far more stable against periodic fields than the classical system. Similar effects will be seen in the interaction of some diatomic molecules with radiation of the correct frequency and it is possible that similar effects may occur in larger molecules.

The destruction of coherence and hence the return to classical behaviour may be achieved in two ways. First, the interaction could be made so short that interferences have insufficient time to build up, and one way of doing this is to make the field so strong that the system ionises quickly. Second, one can break up the coherent waves by introducing phase noise into the driving force, which effectively makes the perturbation a sequence of independent fields each too short for interference effects to act.

It may seem that such problems are of little use and rather esoteric, the quantum numbers being so large. But in studying such problems a great deal has been learnt about the classical and the quantal response of the system and about the relation between the two dynamics; besides producing more efficient computational methods this has increased our knowledge of the fundamental relations between classical and quantal physics which, even after 60 years of study, is far from complete. Furthermore the dynamics of this system is, in certain circumstances, similar to the dynamics of laser excitation of low lying states; paradoxically the experiments on the highly excited systems can be made with far greater precision and better control of important parameters, such as the pulse shapes and field strengths, so it seems plausible that understanding excited atoms in fields may shed light on ground state atoms perturbed by lasers. A more bizarre connection is with the motion of charges in disordered solids, which is important in the theory of electron transport in metals. It transpires that sometimes the equations of motion describing such systems are similar to those of periodically driven atomic systems.

The dynamics of a periodically driven, highly-excited quantal system touches on both unresolved fundamental problems and provides connections between seemingly unrelated areas of physics.

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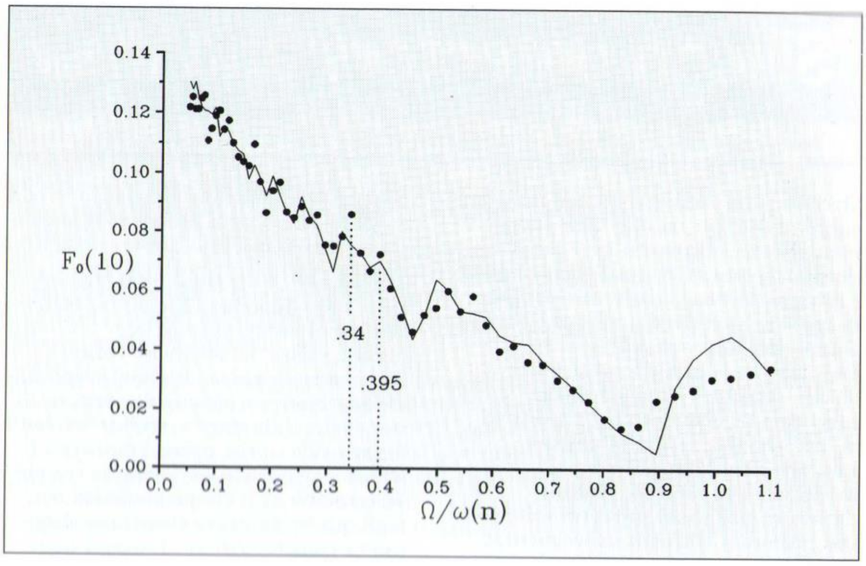

Figure 2: Graph comparing the experimental, •, and classical, solid line, microwave field amplitudes needed to produce 10% ionisation for scaled frequencies smaller than unity. The experimental points nearest to the 1/3 and 2/5 resonances are seen to be locally more stable.

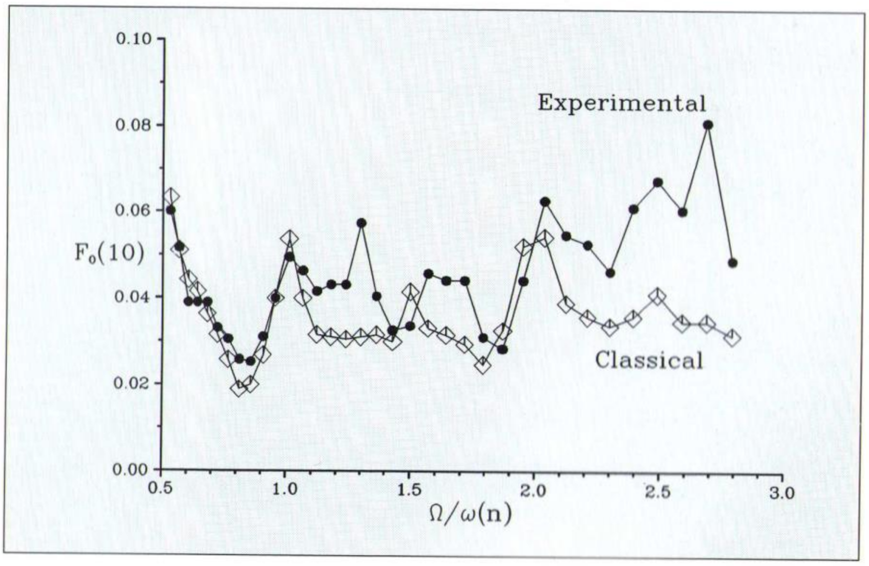

Figure 3: Graph comparing the experimental, •, and classical, ◊, microwave field amplitudes needed to produce 10% ionisation for low scaled frequencies.

Silicon detectors and their applications

Over the last decade there has been a surge of interest among high energy physicists in silicon charged particle detectors, driven originally by a desire for higher spatial resolution to study decays of short lived particles containing heavy quarks. Developments of high precision silicon detectors have led to the invention of new detector types and stimulated the design of custom microelectronic amplifiers to miniaturise apparatus. Silicon detectors also show great promise for the extremely difficult experimental conditions posed by the next generation of accelerators and are widely expected to become popular in other areas of science, writes Geoffrey Hall of Imperial College, London.

Around 1980 the need to gather data on recently discovered charmed particles required measurement of trajectories with a precision of a few microns. This was achieved using microstrip detectors — arrays of narrow p-n diodes, typically 1000 diodes spaced 50 μm apart, each of which acted as an individual sensor. The fact that such devices could be constructed was due to the exploitation of MOS (metal oxide silicon) technology developed by the electronics industry over many years. A few individuals, notably Joseph Kemmer in Munich, developed simple processes to fabricate detectors. The ideas were rapidly taken up by several European and Japanese companies leading to the production of a range of detectors of various sizes and geometries.

The novelty of the fabrication method lay in the oxidation of the silicon as the first important processing step. Silicon dioxide makes the otherwise volatile wafer surface passive. It also provides an ideal medium for etching fine features, using photolithography, so that windows in the oxide can be opened through which implantation of doping atoms can be carried out. Thus precisely defined, high quality diodes of almost any shape can be constructed.

Another feature of silicon dioxide is its transparency over a wide wavelength range. Since silicon is an excellent photon-to-electron converter, photosensitive diodes are a simple extension of particle detectors. They are important to particle physicists too, as scintillation light detectors, with advantages of size, cost and magnetic-field immunity over photomultipliers.

The p-n junction detector

The essence of all modern silicon detectors (except charge-coupled devices) is the p-n diode. The depletion region around the junction forms a useful detection region since there is an electric field and an absence of mobile charge carriers. Then, only when free charges are generated by ionisation does current, in the form of a fast pulse, flow across the junction. The depleted region can be enlarged by an external voltage, up to the thickness of the wafer, to maximise sensitivity to charged particles. This is essential since, unlike many other detectors, silicon gives no internal amplification. The signal produced by a high energy charged particle in 300μm of silicon is about 4fC, or 25,000 electron-hole pairs.

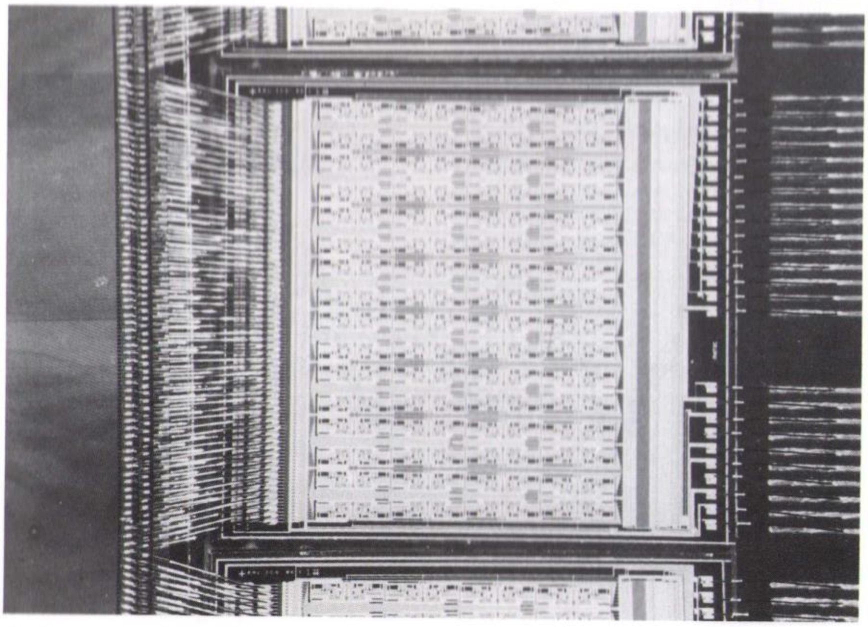

Figure 1: A silicon microstrip detector connected by 25μm wire bonds to a multiplexing amplifier built by RAL in 3μm CMOS technology.

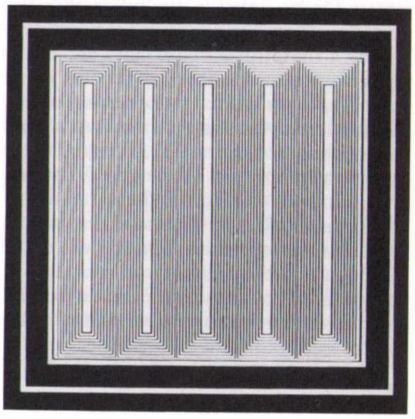

Figure 2: The surface of a silicon drift photodiode opposite the photosensitive side. The detector is divided into five cells with an n-type anode, at the centre of each cell, surrounded by field shaping p-type cathodes. Electrons drift within the wafer up to 1 mm to the anode. The total area of the detector is 15mm x 15mm.

The small signal is the main drawback of these detectors since it requires the use of a low-noise amplifier. However circuits capable of readout noise of 500 to 2000 electrons are now commonplace. Their performance is limited finally by two important properties of the detector — the dark current under reverse bias, which contributes shot noise (see box), and the device capacitance, which attenuates high frequency components of the signal. Leakage currents in silicon detectors can be made extremely low, around nA/cm^2, although this is the main challenge to the manufacturer; capacitance is defined by device geometry.

Current developments

Microstrip detectors are now standard tools in high energy physics experiments. In the UK the pioneering work was done at Imperial College for the NA14 charm photoproduction experiment at CERN in 1982. A system of 10,000 microstrips was instrumented using surface mount amplifiers. Subsequent British developments have focused on microelectronic amplifiers to match the detectors. A highly successful circuit was produced at Rutherford Appleton Laboratory and used in the DELPHI experiment at CERN (figure 1). Miniaturisation of readout circuitry is vital to keep the overall detector compact for installation in colliding beam experiments where both size and power dissipation are major constraints in confined spaces around the beam pipe.

The simplest extension of the microstrip is to produce detectors with strips on both sides. Several designs have been produced which incorporate integrated resistors and capacitors, using different techniques, to be installed in LEP experiments.

More complex detectors have also been invented. If p-type junctions are implanted in *both* surfaces of an n-type wafer, it is still possible to deplete the silicon and a potential minimum for electrons is formed within the wafer. This can be exploited to transport electrons long distances. At Imperial College we have demonstrated detectors where electrons have been drifted over 8mm in 2-50 μsec. They can be used as position measuring detectors with two-dimensional capability — one coordinate comes from the drift time, the other from the position of the readout electrode.

Another application of the drift detector is to construct low capacitance and, consequently, lower noise photodiodes. The anodes in a drift detector are very small and we have designed and tested devices with an order of magnitude less capacitance than conventional photodiodes (figures 2 and 3).

Perhaps the most promising development under way is one that involves a marriage between detector and microelectronic fabrication. A collaboration between Imperial College and Rutherford Appleton Laboratory is building a detector comprising two simple parts: an array of 200μm x 200μm diodes on a single substrate, and a matching array of amplifiers on another. The two pixel arrays are connected by 'bump-bonding' using a low temperature alloy — now proven in British industry. Because of the small size of the detector elements, low noise can be achieved and energy resolution of <700 eV is aimed for. The first prototype amplifier chip has been fabricated (figure 4).

The p-n diode

Silicon is a crystalline material and so the atomic electrons are arranged in bands of energies. Conduction occurs by movement of electrons in the outermost, conduction, band and by motion of hole states in the next lower band, the valence band. In a semiconductor, the gap between the valence and the conduction band is sufficiently large to prevent thermal repopulation of electrons (or holes) if the mobile charge carriers are removed.

In addition the number of charge carriers can be controlled by doping the material, which requires the replacement of silicon atoms by impurities which contribute loosely bound electrons (n-type) or holes (p-type). A diode is typically formed by implanting a high density of p-type atoms into a lightly doped n-type substrate.

A depletion region forms around the junction where almost no mobile carriers exist, as a consequence of electron-hole recombination, and an electrical potential difference is set up. This arises from exposed charges contributed by the ionised doping atoms. The natural potential difference, and thus the depth of the depletion region, can be enlarged, by further reverse bias voltage, or reduced, by applying a forward bias. Thus current flow across the junction is essentially non-existent in the reverse polarity but meets little resistance when forward biased.

This diode behaviour is an important feature of a detector since the small signals generated by ionising events would be swamped from fluctuations (shot noise) in any significant flow of direct current.

Future challenges

A major current concern of particle physicists is radiation hardness since detectors and electronics installed at high intensity hadron colliders will receive substantial doses. Fortunately silicon looks very promising and many of the damage mechanisms are well understood. Attention is now focusing on integrated components.

Outside high energy physics there is growing interest in exploiting silicon technology. As an example, low energy X-rays are ideally matched to absorption by silicon and the advent of high intensity synchrotron radiation sources presents difficulties for those intending to make full use of machine capability. The pixel detector described here would solve many of the problems of high efficiency and high readout rate and would be a marvellous example of cross-disciplinary collaboration.

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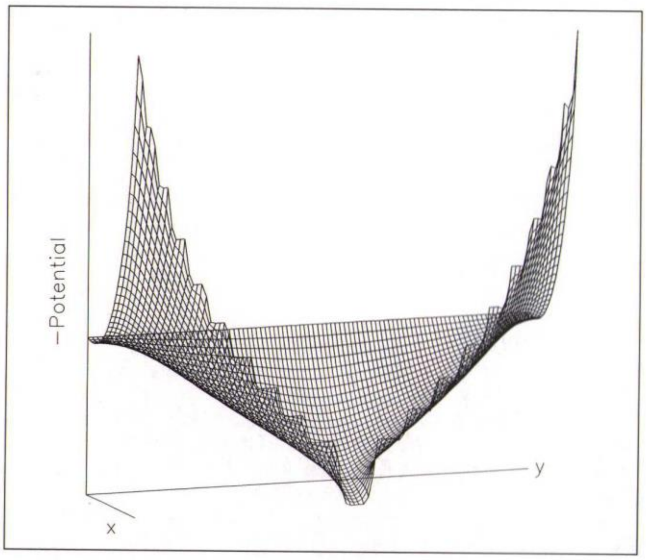


Figure 3: The electric potential distribution in one cell of the photodiode shown in figure 2. Electrons follow the path of steepest descent to the anode.

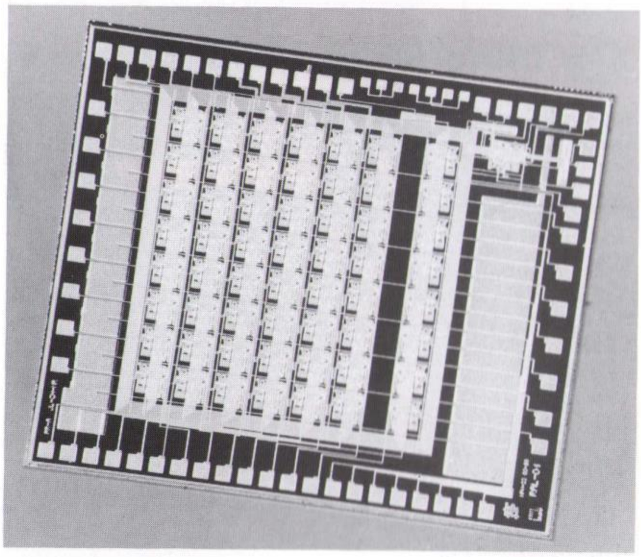


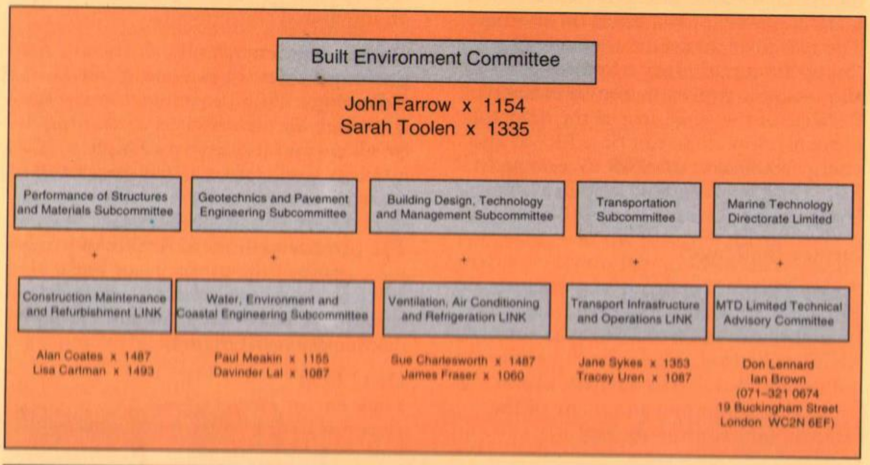
Figure 4: The prototype pixel amplifier chip. It contains 56 identical cells 300μm x 300μm. A full-size version will be bump-bonded to a detector diode array.

The new Built Environment Committee

As reported in the last issue of the Bulletin, there has been a reorganisation of the Environment Committee which, following the Littlejohn Review of Civil Engineering, better reflects the areas of interest of the peer review bodies involved. John Farrow, Group Leader of the Built Environment Committee, explains the changes and highlights some projects.

The Environment Committee gained extra funds from 1983 for the support of civil engineering. The research programme was focused on four areas: structures; geotechnics; repair, maintenance and operation; and hydraulics, pollution control and public health engineering. A strong emphasis was placed on closer collaboration with industry and improved dissemination of research results and to effect this, coordinators were used in each of the areas.

A small advisory panel chaired by Professor G S Littlejohn of Bradford University last year undertook a review of the first five years of support (copies of the report available from the Built Environment Committee Secretariat). Funds devoted to civil engineering were perceived to be well managed with a significant increase in the proportion of grants involving collaboration and industrial contributions, which reflected well on cost effectiveness. Four large-scale facilities — an earthquake simulator, an experimental site for soft clay research, a flood channel facility and an anaerobic waste water treatment plant — were particularly successful in encouraging collaborative research which ranks in the forefront of engineering internationally. The panel found several excellent examples of high quality research that had been undertaken, three of which are shown here.

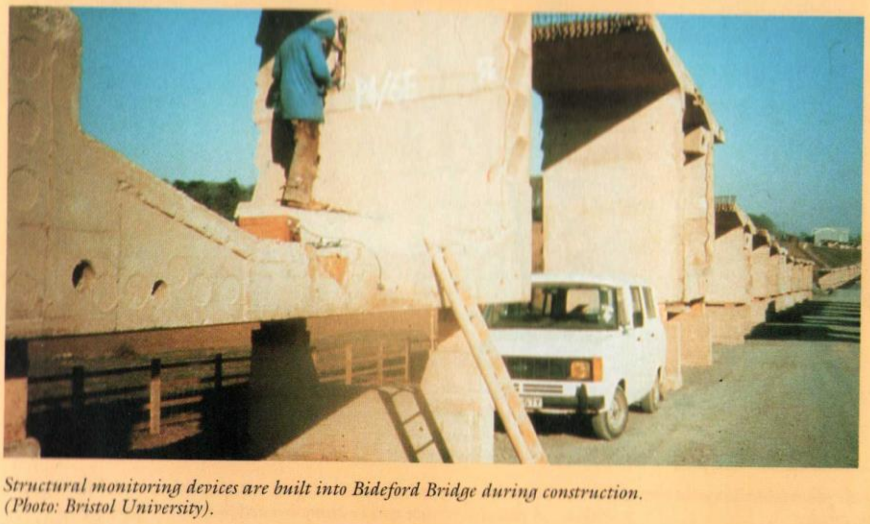


The Civil Engineering Review concluded that more emphasis needed to be placed on full-life engineering performance and a whole-life engineering philosophy should permeate the coordinated programme. As a result of the recommendations, three new Subcommittees based on the broad core disciplines in civil engineering have been created and the titles of the other two Subcommittees and the Committee have been modified to reflect the areas of interest better. This is shown in the diagram.

The Committee has always supported environmentally relevant activities. The Building Subcommittee has had a major initiative aimed at reducing energy use in buildings, which accounts for some 45% of the country's prime energy consumption, and much of the Transportation Subcommittee's budget is aimed at producing more efficient transportation. This emphasis is likely to continue and significant support has already been received for relevant topics within the Clean Technology initiative (see page 7). Provision of safe drinking water, anaerobic digestion of waste and coastal engineering are likely to receive major support in the future.

John Farrow
Built Environment Committee
SERC Swindon Office

Site monitoring of concrete bridges

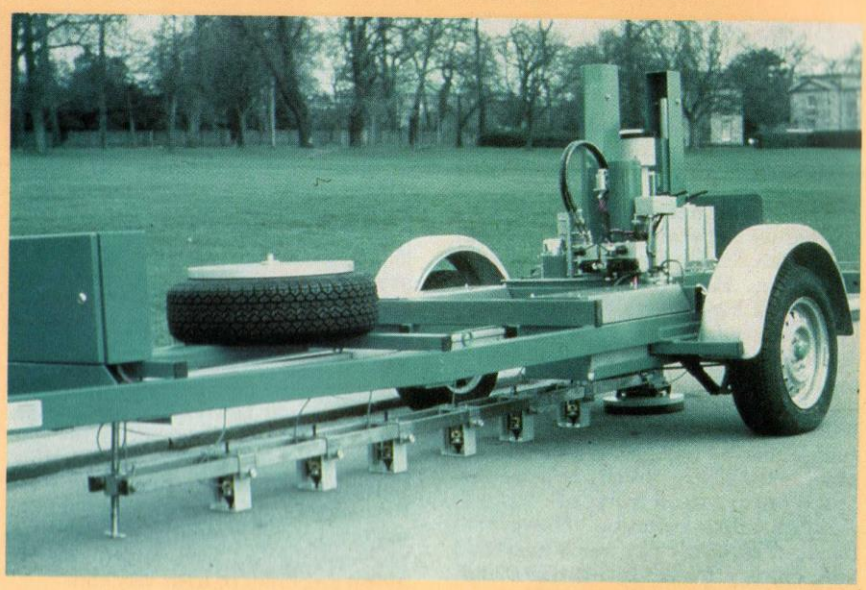


Structural monitoring devices are built into Bideford Bridge during construction. (Photo: Bristol University).

Glued segmental construction of post-tension concrete box girder bridges is a relatively new technique in the UK. Recently, three major bridge structures of this type have been instrumented. Strain gauges and thermo-couples were embedded in the concrete segments by fixing to the reinforcement before casting. Initial readings were taken for shrinkage a few days after casting, when the units were stored ready for erection. After erection, strains were read at regular intervals to monitor the construction process and the in-service performance. Large computer databases containing results of the three bridges have been created and will be used in developing national codes for bridges. This was a cooperative project between Bristol University, the University of Wales College of Cardiff and South Glamorgan County Council.

Pavement design

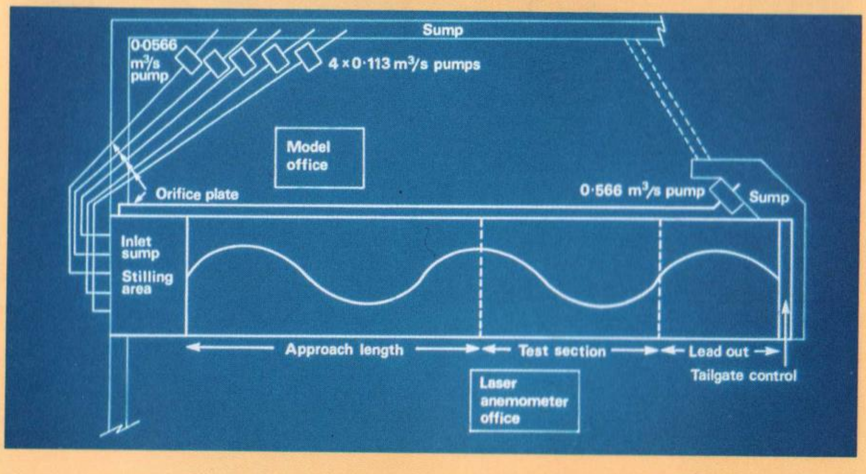
Pavement (road surface) design and performance have been studied at Nottingham University and recent research has concentrated on the falling weight deflectometer for structural evaluation of road pavements. This work has been conducted in connection with the Transport and Road Research Laboratory and has been implemented through a Teaching Company Scheme Programme. Nonlinear elastic models have been applied to pavement analysis and form an important aspect of back-analysis used to interpret data from the falling weight deflectometer.



Falling weight deflectometer (Photo: TRRL, Nottingham University).

Flood channel facility

A large flood channel facility, 56 metres long and 10 metres wide, funded by SERC has been constructed at Hydraulics Research Limited to investigate the complex interaction between flows and river channel and over a flood plain. The size of the channel makes it possible to reproduce flows representative of those that occur in natural rivers, especially those which are strongly three-dimensional in character with a large lateral transfer of momentum between the flood plain and the main channel. The facility is fully equipped to measure not only hydraulic parameters such as discharge, water level, velocity and boundary shear stress, but also the turbulent structure of the flow by means of laser doppler meters. Data is stored and accessed on several microcomputers housed adjacent to the facility.



Meandering river with flood plain configuration of the flood channel facility. (Pictures: Hydraulics Research Ltd).

Solar oscillations

The Sun is our nearest star and much of what we know about the physics of stars relies heavily on our knowledge of the Sun. However most of that knowledge has been gained by a study of its surface layers; we have had to depend on theory to extrapolate into the interior. Yet it is in the depths of the Sun where the fundamental processes occur which produce the energy that we rely on. We cannot observe the centre directly because the Sun is opaque to all forms of electromagnetic radiation. However there are currently two views into the Sun; one is provided by neutrinos and the other is solar oscillations. Yvonne Elsworth of Birmingham University reviews 11 years of solar oscillations.

The Sun forms a resonant cavity for standing sound waves which can exist throughout the Sun. These sound waves cause minute motions of the outer layers of the Sun about 10 metres high which can be detected from Earth. The high resolution spectroscopy group at Birmingham University has been making measurements of these solar oscillations since the mid 1970s.

Our technique uses the Doppler effect to measure the velocity of the solar surface to a precision of much better than 1cm/s for oscillations whose period is about 5 minutes (see box). A complex pattern of many oscillations is seen and an analysis of their frequencies probes the solar interior in much the same way that seismic waves sense the interior of the Earth. Data from solar oscillations provide information on temperature, density and velocity as a function of depth and latitude inside the Sun producing the first detailed picture of the interior of a star from observational data rather than from a theoretical model.

The extraction of the variation of solar structure with depth into the Sun depends on the fact that different modes are confined to different parts of the Sun. Some are just in the surface layers but those that we observe are distributed throughout the Sun which means that the conclusions we draw about the physics of the Sun relate either to its global properties or to its very core.

Earth's diurnal spin

The dominant effect that we see in our data is that the Earth spins once a day! This and two other known velocities, the radial component of the orbit round the Sun and the gravitational red shift predicted by Einstein for light to escape from the gravitational field of the Sun, are of about the same magnitude. We remove all three from the data leaving ripples with an amplitude of a few metres per second. When these are frequency analysed they are seen to be oscillations with periods of about 5 minutes. To get a clear picture of the spectrum, data from many days need to be put together. A typical spectrum is shown in figure 1.

However the fact that the Earth rotates means that the Sun is visible from a given point on the Earth for an average eight hours every day. The consequence of such synchronous breaks in the data is sidebands in the spectrum at a spacing of 11.57 microhertz (or one a day). It is an unkind trick of nature that the spacing of these artifacts is close to that of real structure in the spectrum. For this reason and to compensate for bad weather, we have a network of stations (currently four but soon to be six) placed around the world. The Sun never sets on our apparatus.

Shifting frequencies

There are many results that can be extracted from the data but just two are highlighted here. The first refers to the variation of the oscillation frequencies with solar cycle. Evidence collected over 11 years shows that the frequencies have shifted through the solar cycle at the level of 1 part in 10,000. Figure 2 shows the evidence for this shift and for comparison a scaled version of the Zurich sunspot number is shown on the same graph. The two effects appear to be reasonably well correlated.

Neutrino observations

Neutrinos are also important to the detail of the spectrum. There is currently a problem with the neutrino observations: their arrival rate on Earth is roughly 1/3 the theoretically predicted rate. One solution to this is that the existing understanding of the solar physics of the core is wrong.

The solar oscillations detected by the Birmingham group can be predicted from solar models. It is difficult to build accurate models because of the problems associated with properly representing the

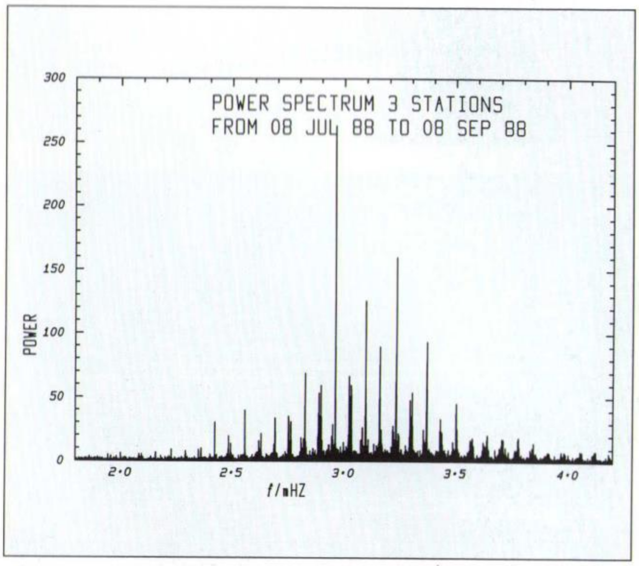


Figure 1: Spectrum of the oscillations from two months of data.

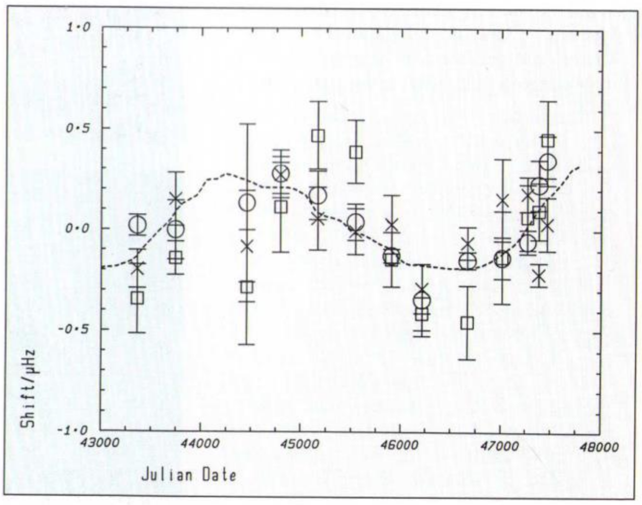


Figure 2: Variation of oscillation frequency with time from 1979 to 1988 in Julian Date. The dotted line shows the variation of sunspot number over the same period. The scale for sunspot number is not shown. The different symbols refer to different modes of oscillation of the Sun.

Experimental basis

Light from the Sun is broadly like that from a black body whose temperature is about 6000K. Atoms in the outer layers (or photosphere) of the Sun absorb and re-radiate some of this radiation over narrow wavelength bands. Because the re-radiation is isotropic, this scattering process leads to dark bands in the solar spectrum which are known as Fraunhofer lines. There are a great many of these lines and the one which is of interest to us is the 770 nm line due to potassium.

Potassium vapour is relatively easily formed on Earth and at the heart of our apparatus is a small quartz cell containing potassium at just less than 400K. When sunlight falls on this cell, scattering will occur in just the same way that the scattering that formed the Fraunhofer line occurred. But because the temperature of the vapour cell is much lower than that of the Sun's surface the absorption line in the cell is much narrower than the Fraunhofer line.

To make the measurement differential, the cell is placed in a longitudinal magnetic field which causes the line to be split into two components according to the Zeeman effect. The situation is as shown in figure 3.

The scattered light is collected and recorded. It is possible to select one or other of the Zeeman lines by polarising the incoming light. The basic measurements are I1 and I2 as a function of time. From these a ratio (I1-I2)/I1+I2) can be formed.

Because the Earth is moving with respect to the Sun, this ratio is non-zero and, over a limited range of velocities, the ratio is proportional to velocity. Because the method compares potassium atoms on the Sun with potassium atoms on Earth and relies on the constancy of atomic physics, the measurement is capable of great precision over a long time.

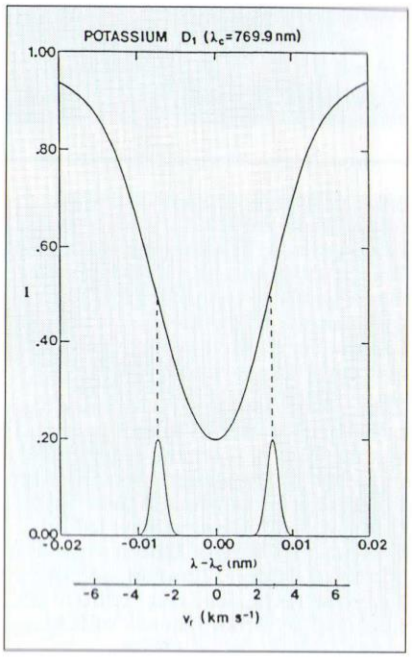


Figure 3: Schematic representation of the solar Fraunhofer line and the absorption characteristics of the Birmingham cells. (Graph drawn for a field of 0.2T).

outer layers of the Sun. However modes can be grouped together so that their differences in frequency are largely dependent on the detail of the solar core. We have measured this fine structure and find that, within errors, the observations agree with the predictions of standard solar models. So it looks as if the solar physics is right and it is neutrino physics which needs altering. Neutrino oscillations and finite neutrino mass could be the explanation.

Both of these results are described in more detail in recent issues of *Nature*. The extensive data base, the good apparatus and very importantly our network of stations (the station in Tenerife is run for us by a group at the Instituto de Astrofisica de Canarias) mean that much more will come out of the Birmingham solar oscillations network over the next solar cycle and beyond.

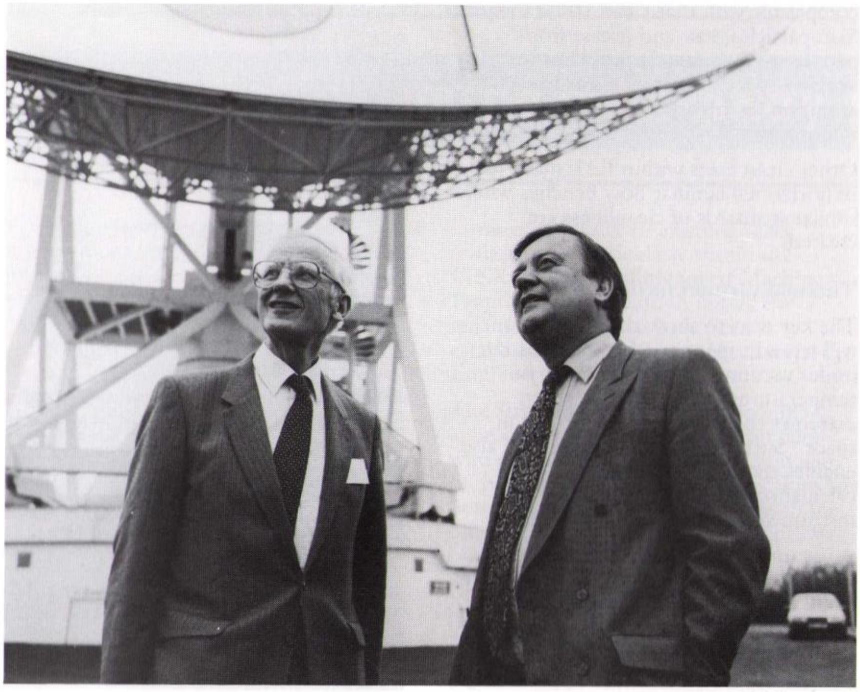
Dr Yvonne Elsworth
Department of Physics and Space Research
Birmingham University

MERLIN — a 230km telescope

Secretary of State for Education and Science, Kenneth Clarke (right) and Professor Rod Davies, Director of the Nuffield Radio Astronomy Laboratories (NRAL) at Jodrell Bank, in front of the 32-metre radio telescope at Cambridge.

A £5 million award to Manchester University through SERC's Astronomy and Planetary Science Board extends the MERLIN (Multi-Element Radio Linked Interferometer Network) to seven telescopes to produce telescope baselines up to 230 km in length, so synthesising a radio telescope 230 km in diameter.

The new telescope is on the Mullard Radio Astronomy Observatory site at Cambridge but will be operated by the NRAL from Manchester.



Environmental test facilities at RAL

Space instruments for both Earth observation and for astronomy must be designed to exacting specifications. They need to be assembled and tested meticulously to ensure that they withstand both the launch conditions and the hostile environment of space and that they work reliably.

Rutherford Appleton Laboratory has recently improved its assembly and test facilities to meet the requirements of the Long Wavelength Spectrometer for the European Space Agency's Infrared Space Observatory, led by Professor P Clegg of Queen Mary and Westfield College, London, and other future projects. The test facilities are described by Brian Diplock of RAL.

Clean rooms

A new clean room facility has been erected that allows large instruments (up to 6m in length) to be accommodated. Clean air down-draught units ensure that a cleanliness standard of Class 100 can be attained. This means there are no more than 100 particles of 0.5 micron size or greater per cubic foot of air. Many instruments for space research rely on optics which have to be kept completely clean.

Access to the facility for large instruments is through doors at either end of a semi-clean unpacking area. Personnel access is through a changing room where coveralls, hoods and overshoes are donned that are compatible with that Class 100 standard. Skin particles, hair and grease from people are the greatest problems in keeping space instruments clean, so attention to this aspect is most important.

Other clean areas within RAL make use of horizontal laminar flow benches where similar standards of cleanliness are created.

Thermal vacuum facility

The key tests to show that an instrument will work in space are those carried out under vacuum over a wide range of temperatures which will cover the extremes that may be encountered in space. Such thermal vacuum testing also enables the thermal designers' calculations to be verified before an instrument is committed to launch.

A vacuum tank capable of taking instruments up to 700 mm diameter and 1500 mm long enables testing to be carried out over a temperature range from -100°C to +72°C. Heating is produced electrically while liquid nitrogen is used to cool below room temperature. Pre-set heating and cooling cycles can be fed into a computer that controls the facility to ensure that correct temperature conditions are applied to the instrument or equipment under test. Evacuation of the tank is carried out by a turbo-molecular pump to be certain that the correct degree of cleanliness is maintained.

A smaller vacuum tank, 550 mm diameter and 800 mm long, is used to bake out instruments and equipment up to 80°C, a cold plate being employed to trap all the volatile materials that are evolved during the bake-out test. By this means a newly assembled instrument can be cleaned up before being placed into the clean vacuum chambers.

A clean air down draught unit is positioned over the entrance of either tank to allow the instruments to be installed into and removed from the tank under clean conditions.

Vibration facility

In a separate building, a new electro-magnetic vibrator is installed having a force rating of 40 kN, to vibrate instruments up to 35 kg mass with accelerations up to 50G. The main reason for vibrating space instruments is to be certain that they will be able to withstand the vibrations that they receive during the launch phase into orbit.

The vibrator can provide both sinusoidal and random 'noise' excitation in three mutually perpendicular axes using an integral 'slip table'.

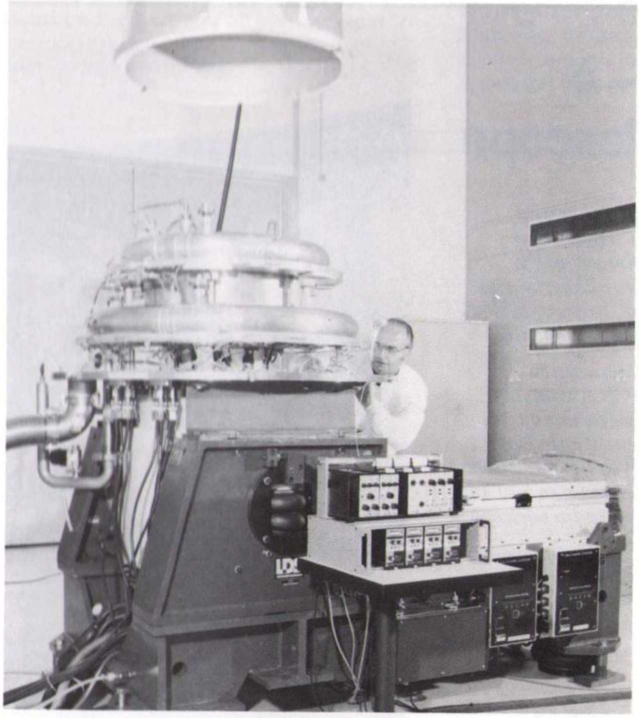
Although most vibration tests are carried out at room temperature, a unique facility within the UK has been designed and commissioned at RAL that allows vibration tests to be undertaken at liquid helium temperature (4K). The instrument under test is mounted on an insulated drive tube within a cryostat that is bolted to the top of the vibrator.

Liquid helium and liquid nitrogen are supplied to reservoirs within the cryostat, and the bracket to which the instrument is mounted is cooled by liquid helium from the reservoir through flexible pipes.

Although the cryostat has been designed to operate at 4K, virtually any temperature between 300K and 4K can be chosen for vibration testing if required.

Use of these facilities allows RAL to carry out most of the integration and tests that are currently specified by the space agencies, NASA and ESA, and helps keep the British academic space community in the forefront of scientific space instrument construction.

B R Diplock
Rutherford Appleton Laboratory



Attaching accelerometers to the RAL liquid helium cryostat on the electro-magnetic vibrator, before vibration-testing the Long Wavelength Spectrometer at 4K. The spectrometer will be one of the instruments on board the Infrared Space Observatory to be launched by ESA in 1993.

High speed machinery video

As part of the continuing effort to inform industrial and academic personnel of the potential benefits of the LINK Programme on the Design of High Speed Machinery, SERC last year commissioned a video, *Manufacturing performance*, for general distribution. The 8-minute video gives typical examples involving industrial and academic establishments in collaborative projects to show how academic research work helps industry produce high performance machinery.

Friction spinning is a form of open-ended spinning in which fibres are twisted between two rotating rollers to produce yarns; a project involving Platt Saco Lowell (UK) Ltd and Loughborough University of Technology has been carried out to understand and exploit the process more rapidly. By using high speed cine, pulsed copper vapour laser equipment and still photography, the mechanism of spinning between rotating rollers has been seen and analysed for the first time. Parallel research has also been carried out into the measurement of the surface finishes of the rollers and into yarn take-up or tensioning systems to facilitate cone winding at higher speeds of yarn deliveries.

Microprocessor controlled, electro-hydraulic warp knitting machinery has been developed at Leeds University, in collaboration with Guilford Kapwood Ltd, to give rapid pattern-changing facilities and high operational speeds. Fast actuation times are achieved by the electro-hydraulic system using special response flow valves and suitably modified demand signals. Further improvements in performance have been attained by introducing feedback signals which respond directly to warp beam diameters and a novel yarn compensator to control both average tensions and cyclical variations in yarn threads. Electronic warp knitting machinery has been tested successfully under production conditions, substantial reductions in changeover times attained, and turnover improved.

Presses used by Metal Closures Ltd employ mechanical linkages which result in slow product changeover times. This situation has been dramatically improved as a result of a collaborative project between Birmingham University and Metal Closures into the synchronisation of drives which utilise high performance dc motors on the presses; high accuracies and stringent synchronisation demands had to be accommodated to attain the benefits of modular press constructions.

Many types of machinery have benefited, and are benefiting, from collaborative projects on the Design of High Speed Machinery, including machinery for metal closures, circular knitting, warp knitting, paper handling, tea-bagging, friction spinning, wire braiding, cartoning, carton erecting, weaving, can forming, -closing, -necking and -pulling, draw texturing, cold roll forming, board making, in-line printing and coining, while machinery for web offset printing, embroidery and winding are currently being considered for research support. Other complementary projects into generic technology, such as microprocessor controlled motors, fast actuators, cams, linkages, mechanisms, sensors and computer control are also being pursued.

Each new project within the Programme receives governmental support of up to 50% of its total cost and should have at least one of these objectives:

- an increase in speed of operation and rate of output between 50 and 100%
- a reduction in changeover time of 50%
- a reduction in rates of rejection by 50%.

A wide variety of industrial companies and academic establishments already participates in the Programme. If you would like to take part, or would like a copy of the video on the Programme, please contact either:

Electronic warp knitting machine (photo: Guilford Kapwood Ltd).

Hugh Thurbon at SERC Swindon Office, telephone (0793) 411117, or

Dr George Sweeney, 8 Hall Hill, Bollington, Macclesfield, Cheshire SK10 5ED. Telephone (0625) 572623.

Survey of office equipment industry

A project to identify possible opportunities for collaborative research between companies engaged in the office machinery and equipment industry and appropriate departments in universities and polytechnics was recently completed. The study excluded computing or telecommunications equipment except where products incorporated such technology.

The study has identified a substantial number of possible research topics. The level of interest in joint projects with universities and polytechnics was generally found to be high.

The Machinery, Plant and Vehicle Industries Subcommittee has decided that most of the projects fall within the terms of reference of existing SERC initiatives — particularly within the LINK Design of High Speed Machinery Programme — although not all the initiatives concerned have been established by the Electro Mechanical Engineering Committee.

The Subcommittee would welcome approaches from academic researchers who might be interested in pursuing any of the topics identified. Introductions to potential collaborating companies in the office machinery and equipment industry can then be made.

In the first instance approaches should be made to:

Hugh Thurbon at SERC Swindon Office, telephone (0793) 411117.

Glasnost in science

The recent changes in the Soviet Union have increased the possibilities for fruitful collaboration between British and Soviet scientists. In the spirit of the new age of *glasnost*, SERC has been forging several agreements aimed at stimulating Anglo-Soviet collaboration, writes Andrew Le Masurier of SERC's International Section.

Joint Memorandum with the USSR State Committee for Science and Technology (GKNT)

GKNT is the Soviet government body responsible for developing a national policy for science and technology. It has defined a set of priority areas, based on their potential contribution to the economic development of the USSR (see box). In May 1990 a delegation from the State Committee visited the Rutherford Appleton Laboratory (RAL) and agreed a Joint Memorandum with SERC, in which both sides undertook to encourage collaboration between British and Soviet researchers.

As a result of this agreement several joint activities are being planned. In addition to meetings on such topics as biotechnology, information technology and academic-industrial liaison, scientists at RAL are pursuing collaborations in two areas.

The first is the use of neutrons in biology. Neutrons are a powerful probe of structure and dynamics in condensed matter and the Isis facility at RAL is the world's most powerful source of pulsed neutrons. Soviet scientists, in collaboration with British researchers, wish to exploit the use of pulsed neutrons in biology. Isis can, for example, be used to study the structures of biological molecules (such as drugs or enzymes) and biomolecular assemblies (such as protein monolayers and model membranes) and also the dynamics of molecules such as proteins and nucleic acids in solution. Professor John Finney (RAL) hopes that a collaborative arrangement can be made for the use of Isis which will also help British scientists to obtain isotopes from the Soviet Union for use in neutron and nuclear structure experiments.

The second area is the development of new laser technologies. High power lasers, such as the Vulcan laser at RAL's Central Laser Facility (CLF), can generate high density, high temperature plasmas important to many areas of plasma physics, such as astrophysics, X-ray laser and fusion studies. CLF staff led by Professor Mike Key are now developing novel krypton fluoride (KrF) excimer lasers which can generate high power pulses more efficiently and more cost-effectively than neodymium glass lasers such as Vulcan. An essential step is the development of pulsed power for the electron beams which the KrF lasers drive. The USSR has considerable expertise in this area and Professor Key is planning to collaborate with appropriate Soviet scientists.

The Soviet Union's 15 priority topics

GKNT has attached priority importance to the following areas:

- **High energy physics**
- **High-temperature superconductivity**
- **Mars**
- **Human genome**
- **New information technologies**
- **Technologies, machines and processes for the future**
- **New materials**
- **Advanced biological engineering methods**
- **High-speed ecologically clean transport**
- **Ecologically clean power engineering**
- **Resource-saving and ecologically clean metallurgic and chemical processes**
- **High-efficiency food production processes**

Soviet delegation visits RAL

A delegation of top-ranking Soviet scientists, who visited Rutherford Appleton Laboratory in November 1990, being shown round the Electron Beam Lithography Facility by the Facility's Head, Ron Lawes (left). They were Academicians Alferov and Nefedov (both Vice Presidents of the USSR Academy of Sciences), Academician Gulyaev (leader of the delegation and Director of the Institute of Radioengineering and Electronics) and Professor Shmelev of Moscow State University. On the right of the picture is Dr P R Williams, Director of RAL.

Visiting with the party were members of the Parliamentary and Scientific Committee Lord Stoddart and Sir Gerard Vaughan MP. The visitors also toured the Joint European X-Ray Telescope (JET-X) and Isis, the pulsed neutron source.

Aide Memoire with the Soviet Academy of Sciences

An Aide Memoire between SERC and the Soviet Academy of Sciences (the main agency for support of basic science in the USSR) has been negotiated. Like the agreement with GKNT, this is a high-level enabling document aimed at promoting Anglo-Soviet collaboration, particularly in the following areas: mathematics and theoretical physics, synchrotron radiation, theoretical computer science, high temperature superconductivity, novel materials, space observation of the atmosphere, advanced biological engineering, excimer lasers, transputers, nanotechnology and molecular electronics.

Molecular electronics and nanotechnology

These are two areas of growing importance to both the UK and the USSR. Molecular electronics is the exploitation of molecular materials in electronics and the fabrication of devices at a molecular scale. It is a field that has developed rapidly in response to a need for electronic devices that are faster and more sophisticated than those based on traditional materials. Nanotechnology has implications in many scientific and engineering disciplines and could be said to be the ultimate in precision engineering — to a scale where dimensions can be measured in terms of atomic diameters.

SERC's Materials Commission has signed an agreement with three Soviet institutions — the Academy of Sciences, the Society for Science and the Laboratory for Molecular Electronics and Nanotechnology — to develop and maintain cooperative research activities in molecular electronics and nanotechnology. As a result of this agreement, two meetings are being arranged, one in the Soviet Union and one in the UK.

Wind energy

Protocols of understanding have been signed for a three-year collaborative venture on the development of wind turbines, involving the RAL Energy Unit, led by Professor Norman Lipman; Imperial College, London, and its industrial partners (Clayton Energy Systems and Dale Electric of Great Britain Ltd); the Moscow Energy Institute; and the Moscow Aviation Institute. The objective of the work is to improve the design of wind turbine systems and to apply the developments to a large-scale demonstration project in the USSR.

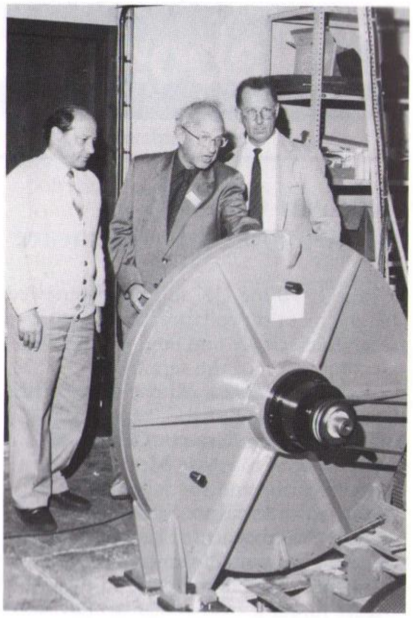
Robotics

A delegation from the SERC Built Environment Committee, led by Professor John Roberts of South Bank Polytechnic, travelled to Moscow in May 1990 and visited the Soviet Institute for Mechanical Engineering Research, the Institute for Problems in Mechanics and the All Union Research Institute for Construction and Road Building Machinery. An agreement was signed to promote collaboration, mainly in the development of robots, such as brick-laying and climbing robots, for use in the construction industry.

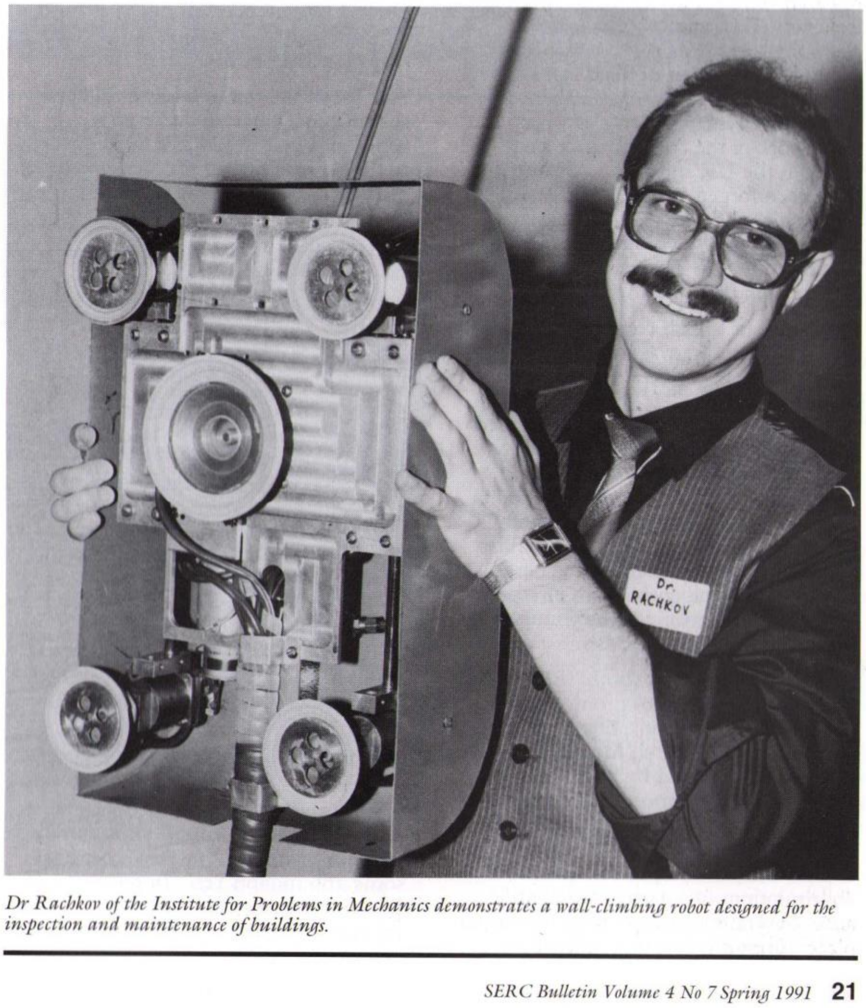
Transputers

Dr Mike Jane of RAL, coordinator of the SERC/DTI Transputer Initiative, organised the British participation in the first Anglo-Soviet symposium on transputers held in Moscow in June 1990. Following the symposium, a memorandum of understanding was signed with the Soviet Transputer Association, in which they agreed to collaborate on developing transputer systems and software.

Dr A Le Masurier
SERC Swindon Office



Norman Lipman (centre) explains the working of the flywheel energy store, an important component of the wind turbine project, to Boris Kazandzhan, Director of Energy Studies at the Moscow Power Institute. On the right is Tony Black, an engineer from Clayton Energy Systems, makers of the flywheel store.



Dr Rachkov of the Institute for Problems in Mechanics demonstrates a wall-climbing robot designed for the inspection and maintenance of buildings.

Collaboration with Japan

Renewal of SERC/ Monbusho Aide Memoire

In June 1990 the UK and Japan renewed an agreement on collaboration in basic research in science and engineering with the completion of the signing by Professor Sir William Mitchell CBE FRS, then Chairman of SERC, and Mr T Kawamura, then Director General of Monbusho, of the Aide Memoire between SERC and the Japanese Ministry of Education, Science and Culture (Monbusho). The Aide Memoire is essentially an enabling document and is not supported by any specific funding arrangements. Revisions to the agreement included the addition of some new British and Japanese contacts as well as extension of the scientific fields covered. The British contacts act as a focal point for specific areas of science, coordinating British collaborative activities within their area and providing advice to those considering for the first time joint research ventures with their counterparts in Japan. The renewal of the Aide Memoire (originally signed in 1982) symbolised the wish of SERC and Monbusho to maintain and enhance cooperative research activities within the framework of the cultural agreement between the UK and Japan. Strong links have been forged between staff at British universities and SERC establishments and their Japanese counterparts during participation in cooperative projects arising from the Aide Memoire.

A meeting of British contacts named in the Aide Memoire was held in London in July 1990 to review progress during the preceding year. It was noted that Anglo-Japanese contacts had continued at a high level and cooperative research projects were now well established in several of the scientific areas included in the agreement. Senior research staff from both countries had made useful exchange visits and there was general agreement on the enthusiasm in Japan for more long-term visits by young British researchers.

A number of schemes (both SERC and other agencies) exist to promote Anglo-Japanese collaborations, one of which is the Advanced Research Meeting mechanism operated by SERC. These are short-duration meetings of an exploratory nature between small numbers of researchers from different countries to discuss possible future collaborations in a particular scientific area. Several fruitful meetings have taken place during the last year under the auspices of the Aide Memoire and arrangements are proceeding for the following meetings in 1991 and 1992:

- Polymer science initiative
- Molecular materials for electronics
- High resolution spectroscopy

An information pack providing details of schemes available to support Anglo-Japanese research collaboration is available from:

Miss Claire Freebury or Mrs Audrey Williams, International Section, SERC Swindon Office; telephone (0793) 411498 or (0793) 411036.

UK/Japan agreement on muon research

An agreement was signed on 28 September 1990 by Professor Sir William Mitchell and Professor Minoru Oda, President of the Japanese Institute of Physical and Chemical Research (RIKEN) under which the Japanese organisation will provide a complex of muon beamlines on Isis, the spallation neutron source at SERC's Rutherford Appleton Laboratory.

The use of the muon facility will be shared equally between scientists sponsored by RIKEN and SERC over the 10-year period of the agreement. Further information can be obtained from:

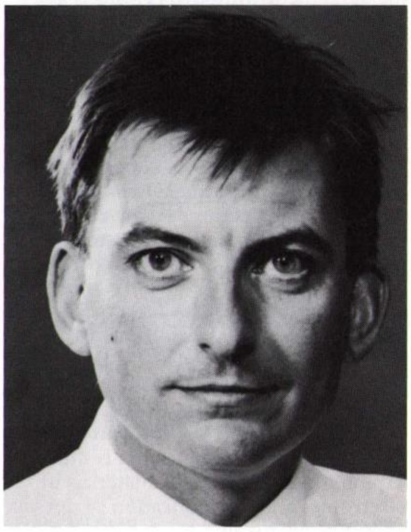
Dr W G Williams, Neutron Science Division, Rutherford Appleton Laboratory; telephone (0235) 445599.

MARI instrument on Isis

The official opening ceremony of MARI, the newest instrument at Isis, took place at RAL in November 1990. The MARI spectrometer is the result of a collaborative venture between the UK and Japan (see *SERC Bulletin* Volume 4 No 4, Spring 1990). This collaboration, initiated in 1986, was the creation of the late Professor Yoshikazu Ishikawa, whose widow performed the opening ceremony. The spectrometer is named 'Ma-Ri' — the Japanese for 'Truth' and the name of Professor Ishikawa's daughter.

The MARI spectrometer was funded by the Japanese Ministry of Education, Science and Culture (Monbusho) as part of the UK-Japan Collaboration on neutron scattering. Its basic cost was some 266 million Yen. In return, Japanese scientists have access to the Isis Facility.

New head of UK Research Councils' European Office



Dr Alf Game

Dr Alf Game, formerly group leader of SERC's Electro Mechanical Engineering Committee, took up post as Head of the UK Research Councils' European Office in Brussels in November 1990, replacing Wendy Light. The services of the Brussels Office, which include an advisory service to researchers on European Community matters, early warning of calls for proposals, closing dates and changes to the nature and priority of programmes, are available to all universities and polytechnics at an annual 'Brussels Club' subscription fee of £1750.00.

'Brussels Club' seminars are held annually in the UK. The last meeting, held at the AFRC Institute of Arable Crops Research at Rothamsted in June 1990, was extremely successful, attracting 110 participants. The programme included presentations by three speakers from the European Commission, covering the Third Framework Programme, Cooperation with East Europe and Science Collaboration with Less Developed Countries, together with speakers from the Cabinet Office Science and Technology Secretariat and the British Council's Rome Office.

Further details and enquiries regarding 'Brussels Club' membership can be obtained from Alf Game, Gaynor Whyles or Ruth Wilson at the Research Councils' European Office, BP10, Rue de la Loi 83, 1040 Brussels; telephone 010-322-230-5275.

Intel iPSC/860 hypercube computer at Daresbury

The first Intel iPSC/860 parallel computer in Europe was installed at Daresbury in July 1990. The iPSC/860 comprises a number of processing nodes, each using the revolutionary i860 chip from Intel Corporation. This 64-bit RISC (reduced instruction set) style chip has vector-pipelining capabilities which render it ideal for scientific computing, yielding a single-processor performance similar to that of the Convex C-220 mini-supercomputer (also at Daresbury). We have seen 40 Mflops per processor in applications using assembler-coded matrix-vector operations.

Each node has a single processor, currently 8 Mbytes of local DRAM memory and hardware to connect to a hypercube bus for data transfer to other processors and to disk. In the Daresbury configuration, 32 nodes are linked in a hypercube topology to increase the computational power. In programming the machine it is possible to route data between processors explicitly so that a single task can be decomposed for parallel execution. The Advanced Research Computing Group at the Laboratory has established a lead in this type of programming over the last four years. This can now be done systematically in a number of major application areas, and it has even been found beneficial to develop portable tools, using a similar philosophy, as an interface to other computers.

There are to date around 100 projects which have used the parallel resources supported at Daresbury. Most of these are now migrating on to the i860 machine. As well as the Collaborative Computational Projects (CCPs — see *SERC Bulletin* volume 4 No 5, Summer 1990) something like 30 individual research groups in universities and polytechnics already have access over the Joint Academic Network (JANET) and are actively collaborating in parallel software development. This number is growing steadily as is awareness of the potential impact of parallelism for high-performance computing in science and engineering.

For suitable applications, it is now possible to exceed the performance of a Cray X-MP at a much lower cost. The aim is to use the Intel hypercube both to investigate new fields, drawing on the experience already gained to parallelise new codes, and to support a small number of front-line projects which will tax this new resource to its utmost.

For further information, contact **R J Allan** and **M F Guest**, Advanced Research Computing Group, Daresbury Laboratory.

Minister meets Heads of Research Councils

Alan Howarth (left) and Sir David Phillips KBE, FRS, Chairman of the Advisory Board for the Research Councils (both seated), with the 'HORCs' (left to right): Dr Dai Rees FRS, Secretary, Medical Research Council; Professor John Knill, Chairman, NERC; Professor Howard Newby, Chairman, ESRC; Professor William Stewart FRS, Secretary, AFRC; and Tony Egginton CBE, Deputy Chairman, SERC.

Alan Howarth CBE, MP, Junior Minister for Science, attended a meeting of the Heads of the UK Research Councils held at Polaris House, Swindon in September 1990. Mr Howarth has responsibility within the Department of Education and Science for the science budget and the Research Councils.

After his meeting with the Heads of Research Councils, Mr Howarth toured three of the Councils: the Agricultural and Food Research Council, the Natural Environment Research Council and the Science and Engineering Research Council.

Commenting on his visit Mr Howarth said:" Having recently taken up my new appointment as Minister responsible for Higher Education and Science, I am very pleased to have had the opportunity today to meet the heads of all five Research Councils and some of the staff in three of them. I am glad to see that such good progress has been made in gathering the councils together on the Polaris House site."

By April this year, the site will house the Agricultural and Food Research Council and the Economic and Social Research Council in new extensions, as well as the Natural Environment Research Council and the Science and Engineering Research Council who are already based there.

'Young scientists' meet in Edinburgh

As part of the 25th anniversary celebrations of the founding of SERC, the Council sponsored a meeting in Edinburgh at the new Heriot-Watt Conference Centre of what were intriguingly referred to as 'young scientists'. The idea was to bring together many of the brightest young research workers in the UK and let them describe to each other what they considered to be the key issues in their own fields of expertise as well as discuss their perceptions of the major issues and problems facing young scientists in the UK today. Malcolm Longair of Cambridge University (and until 31 December 1990 Director of SERC's Royal Observatory in Edinburgh) reports on the conference.

The 'young scientists' invited to attend this event included all SERC Advanced Fellows and all Royal Society Research Fellows working in the areas supported by SERC. To these were added a selection of young research workers from industry and from SERC establishments as well as a number of lecturers who were appointed through the new blood scheme. Almost 100 scientists were able to come to Edinburgh for the meeting, in the age range of about 30 to 35, so that all had had significant post-doctoral experience. They were therefore familiar with the problems facing young research workers.

The programme of lectures was designed to span the full range of disciplines supported by SERC. The six science sessions covered

- Astrophysics, geophysics and the environment
- Solid state chemistry and physics, and materials
- Process engineering, electromechanical engineering and manufacturing technology
- Particle physics and nuclear structure
- Biology, biochemistry and biotechnology and
- Mathematics, information technology and computer science.

The Chairmen of SERC's Boards were invited to propose names of young scientists who could provide talks of the highest scientific quality and also be effective science communicators for their disciplines. Each session was introduced and moderated by a senior scientist, normally Chairman of one of SERC's Boards or a member of its Council.

This is not the place to describe what the invited speakers said. The one thing that was striking was their outstanding ability to communicate to those outside their fields of specialisation. It is encouraging that this type of interdisciplinary communication can be made to work and that specialists in as diverse fields as plant molecular biology, elementary particle physics, electrical engineering, mathematics and superconductivity can appreciate each others' problems. This was clearly shown by the range of penetrating questions addressed to each speaker, most of which came from those far outside the discipline being described.

Following the six science sessions, Professor Sir William Mitchell, the then Chairman of SERC, led the final session, and his conclusions would, I believe, be broadly agreed by all of those present. First of all, it was plain that, despite the diversity of current research, there were common themes running through the whole of science and engineering. On an obvious level, many technologies are common to diverse fields of research. Another general theme was the interaction between physics and chemistry at the elementary level and the way in which matter behaves *en masse.* The point was repeatedly made that complex systems are now being studied throughout the whole of science and engineering and that techniques used both at the atomic and macroscopic levels are needed to understand the problems. In cosmology, for example, the current view is that the large-scale properties of the Universe are closely related to particle physics but to create the one from the other requires an understanding of complex processes. Nonlinear processes play an essential role in essentially all fields of research. Good examples include phase transitions, not only in superconductors and throughout solid state physics but also in the phase changes which are believed to occur in the early Universe. Sir William expressed the view that no one part of this edifice of science and engineering could be considered more 'fundamental' than any other. The understanding of superstrings may be the most elegant and beautiful theory of everything but there are equally challenging problems in understanding complexity, for example in studies of the origins of life, of the use of recombinant DNA to produce pharmaceuticals and of chaotic processes.

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Professor Sir William Mitchell with some of the speakers at the Young Scientists Conference (left to right): Dr M Hoare, University College London (biochemical engineering); Dr D Jones, Liverpool University (string theory); Professor J Barrow, Sussex University (the microwave background); Dr R Nicholas, Oxford University (semiconductor design); Dr P Glendinning, Cambridge University (chaos theory); Sir William Mitchell; Dr R Laming, Southampton University (optical fibres/telecommunications); Dr A Osbourn, Sainsbury Laboratory, Norwich (plant pathogens); and Dr V Gibson, Cambridge University (charge parity violation).

'Once in a lifetime' Young Science Fortnight

Stephen Smith, aged 17, of Widnes in Cheshire, attended the 32nd London International Youth Science Fortnight in July-August 1990. This 'once in a lifetime' experience was made possible for him through sponsorship from SERC's Holmes-Hines Memorial Fund. His enthusiastic report on the event shows that it was both enjoyable and enlightening.

The London International Youth Science Fortnight is aimed at bringing together young people (more than 300 of them) from different cultures and backgrounds in the hope of creating more understanding and tolerence. As science is getting more and more important in everyday life and affects us all, it is a firm basis on which to build such an occasion.

Throughout the Science Fortnight there was a mixture of both scientific and social events, of which each participant had a choice. As I am interested in a future medical career, the majority of my scientific programme was medically oriented, consisting of visits to St Bartholomew's Hospital, the Royal Marsden Hospital, and Cambridge University's Physiological Laboratory. All the visits gave me a deeper insight into the life ahead of me, once my 'A' level studies are completed.

Also included in the science programme were lectures and demonstrations which were attended by all participants. Such events were concerned mainly with chemistry and physics, which I enjoyed greatly. Many lectures gave rise to discussion and comparison of the use of science on the international scale. Indeed, the ethics of science was a major topic throughout the two weeks, allowing discussion on such subjects as embryo research, genetic engineering and vivisection.

The Science Fortnight gave me the opportunity to meet and talk with people from other countries, and to ponder over the uses of scientific achievements. It makes science more interesting. Most importantly, it taught me to be more tolerant and respectful towards the people and the world around me.

I would thoroughly recommend the Scientific Fortnight to anybody who is interested in science and its uses, and am grateful to the Holmes-Hines Memorial fund for sponsoring me.

Stephen Smith

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A major concern voiced by most participants was the need for greater endeavours in publicity and public education in the sciences and in technology. Everyone was concerned by the fact that the UK does not appear to do as well as other countries in stimulating the interests of the average tax payer in science and engineering. Professor Alexander Donnachie told a splendid story of being asked by two peasants in the Italian Alps about the latest news on the W and Z bosons and about cold fusion. It is sensible to ask whether one might encounter the same on Snowdon or the shoulders of Ben Nevis. (I should recount an equally amusing true story — on an expedition to the Cuillins in Skye, my family and I met only two people all day in the course of a seven hour slog to the main ridge and they were professors of physics at Edinburgh and Bath!). It was regarded as a high priority that everyone should participate in the public dissemination of knowledge and understanding about what is happening in science now.

Another issue raised by Mr Gerard Fairtlough was the importance of not losing sight of good ideas which might be exploitable by industry. Intellectual Property Rights is an important issue. There is no question but that most of the research supported by SERC is appropriately done for its own sake. He emphasised, however, that many of the ideas are exploitable and the research workers who have the ideas should be fully aware of the advantages of patenting those which might have industrial application. Education in patenting would do no end of good for demonstrating the relevance of the pure scientific research activity to the health of British industry.

The overall impression of the meeting was one of the enormous enthusiasm and ability of the current generation of young scientists and engineers. It is most encouraging that meetings such as this can take place and that specialists who are at the forefront of their own fields can communicate in a positive and enlightening way to their colleagues in totally different disciplines. We were not expecting that suddenly we would find great connections between botany and elementary particle physics or between superconductivity and biochemical engineering but what people did grasp was the nature of the problems being tackled in each area. I am sure that this experience is bound to influence the thoughts of bright research workers, even if it is at the subliminal level. Many of us are convinced that we must not wait until the 50th anniversary of SERC before this enlightening and refreshing exercise is repeated.

Professor Malcolm S Longair,
Jacksonian Professor of Natural Philosophy, Cambridge (and formerly, Director, Royal Observatory, Edinburgh).

Translated Soviet scientific journals

The British Library Document Supply Centre has a translated journals programme primarily from Russian into English. The eight leading, substantial Soviet science and technology titles in the programme are:

International polymer science and technology
Organometallic chemistry in the USSR
Russian chemical reviews
Russian journal of inorganic chemistry
Russian journal of physical chemistry
Russian mathematical surveys
Steel in the USSR
Thermal engineering.

For further information, contact
Andea Seed
The British Library Document Supply Centre,
Boston Spa,
Wetherby,
West Yorkshire LS23 7BQ.

Telephone (0937) 546078.

Starlink's 10th birthday

For ten years the nationwide network of data analysis computers Starlink has served the computing needs of British astronomers. And to celebrate the 10th anniversary in October 1990 of the official opening of the network, the Rutherford Appleton Laboratory, who manage the network, organised a discussion meeting at the Royal Astronomical Society, with talks on the astronomical research carried out with the aid of Starlink across the whole wavelength range.

Starlink plays a key role in British astronomy, processing the vast quantities of data produced by modern astronomical techniques. Six VAX computer systems were installed at major astronomical centres around the country in 1980, since when the number of users, who access the system through the JANET network, has grown from 110 to about 1300 — virtually every British astronomer.

The primary objectives of Starlink are:

- To provide and coordinate data reduction and analysis facilities for British astronomers
- To encourage software sharing and standardisation to prevent unnecessary duplication of programming effort.

Studentships

SERC awards 1990-91: more nominations

At the start of the 1990-91 academic year, nominations for SERC awards were showing a marked increase over the same period in 1989-90. Standard research award applications had increased by 4%, and advanced course applications by 11%, but the most significant increase was the number of CASE (Cooperative Awards in Science and Engineering) nominations: these increased by 52%, with a total of 1239 applications received by mid-October (compared to a total of 814 in 1989-90). This increase could largely be attributed to the introduction of the CASE pool which attracted applications from departments which had no quota places or had used up their quota allocation. The increase of at least £1,000 a year in CASE students' stipends (£250 from SERC and a minimum of £750 from the cooperating body) could also account for this substantial increase in nominations.

Good news for students

In June 1990, SERC amended several of its regulations in an attempt to encourage more graduates to take up research awards. Until then, students who had undertaken previous postgraduate training had their research awards reduced by an equivalent amount of time. This no longer applies to those with masters degrees. So, from this academic year, students who have obtained an MSc or an MPhil (or an equivalent qualification arising from a SERC-supported course) and who would previously have had a year or more deducted from their research award are entitled to a full three years of support. Other postgraduate training is, however, still deductible.

New allowances for students with disabilities

From 1 October 1990, students who, because of a disability, incur additional costs have been able to claim new allowances. In addition to the existing increased allowance of £1,000 a year for extra day-to-day expenses (such as special diets or travel), students can now claim up to £4,000 a year for non-medical helpers and up to £3,000 during the life of the award for specialist equipment needed for their studies. More details can be obtained from the Postgraduate Training Support Section at SERC Swindon Office; telephone (0793) 411463.

PhD submission rates

Sanctions threshold to increase in 1993.

At its February meeting, the Council decided to raise the level of PhD submission rates below which mandatory sanctions are applied from 35% to 45% . From 1993, Departments that fail to achieve this level may be sanctioned.

Some new publications from SERC

Unless otherwise stated, all publications are available free of charge from SERC Swindon Office, telephone (0793) 41 + extension number.

SERC annual report

Copies of the *Science and Engineering Research Council report for the year 1989-90* are available from Jane Jefferies, Public Relations Unit, ext 1256.

Comparison of research resources

A two-volume report, *Research in the United Kingdom, France and West Germany: a comparison*, by Harry Atkinson, Philippa Rogers and Richard Bond, is available from Mr Bond, ext 1249, price £10 for Volume 1 and £15 for Volume 2.

Biological sciences

Copies of *A strategy for biological sciences* and the *Image Interpretation Initiative newsletter* are available from Dr Steve Milson, ext 1136; *Molecular Recognition Initiative newsletter* from Dr Colin Miles, ext 1446.

Astronomy

Copies of the *SERC-NWO* (Netherlands Organisation for Scientific Research) *Joint Steering Committee annual report* are available from Nansi Blyth, ext 1017.

Nonlinear optics

The latest issue of *NLO Update*, the newsletter of the Nonlinear Optics Initiative, is available from Steve Johnstone, Physics Secretariat, ext 1215.

Magnetics

Copies of *Magnetism and Magnetic Materials Initiative community document* are available from Dr Alison Spalding, Secretary of the Condensed Matter Physics Subcommittee, ext 1361.

Science-based archaeology

Copies of the *Science-based Archaeology Coordinator's report 1986-89* are available from Steve Johnstone, Physics Secretariat, ext 1215.

Research grant applications

Copies of *SERC research grants: a beginner's guide* are available from Carol Exton, Finance Division, ext 1077.

SERC enquiry points

To make it easier to find the right person when you telephone our administrative offices in Swindon (or elsewhere), we have updated our list of key contact points. Except where otherwise stated, all extension numbers are at SERC Swindon Office. The switchboard number is Swindon (0793) 411000 (for extensions beginning 2); or dial Swindon (0793) 41+ extension number. The central fax number is Swindon (0793) 411400.

ASTRONOMY AND PLANETARY SCIENCE DIVISION

Studentships and fellowships — RC Hodgon, ext 1267

Ground-based Programme Committee

International activities — ext 1417
UK activities — Dr PB Sharma, ext 1416
Research grants — RC Campbell, ext 1195
PATT awards — Mrs S Fuller, ext 1259

BRITISH NATIONAL SPACE CENTRE

Space Science Programme Board and Earth Observation Programme Board

(SO: Swindon Office; DBH: Dean Bradley House. 071-276 + extension)

UK activities — Dr RLT Street, SO ext 1265
Research grants — RC Campbell, SO ext 1195
International activities — Dr PCL Smith, DBH ext 2429
Microgravity — Mrs Y Windsor, DBH ext 2441
ESA fellowships & Young Graduate Trainee scheme — A Blizzard, DBH ext 2438

ENGINEERING DIVISION

Building technology, design & management — Miss S Charlesworth, ext 1487
Structures and materials — A Coates, ext 1487
Geotechnics; water, environmental & coastal engineering — Dr P Meakin, ext 1155
Transportation — Miss J Sykes, ext 1353
Electrical and power industries — Dr C Brodey, ext 1350
Aerospace industries — Dr A Rawlins, ext 1143
Machinery, plant and vehicle industries — H Thurbon, ext 1117
Particulate and coal technology — Dr NV Pratt, ext 1484
Chemical engineering — DC Illingworth, ext 1492
Separation processes — Miss H Wray, ext 1476
Joint ESRC-SERC — Dr J King, ext 1429
Education and training — Dr R Liwicki, ext 1429
Interdisciplinary Research Centres; design — Mrs DC Herbert, ext 1431
Clean technology — Dr N Lawrence, ext 1122

DIRECTORATES

ACME (including manufacturing processes) — Mrs G Ford, ext 1106
Biotechnology — J McIlherron, ext 1310

Information Technology

JFIT — N Williams, ext 1478
Systems engineering — Dr DM Worsnip, ext 1104
Control and instrumentation — T Willis, ext 1401
Communications and distributed systems — Ms C Ewart, ext 1436
Devices technology — PN Burnell, ext 1161
VSLI design and optoelectronics — Dr JM Seed, ext 1346
Speech & vision; parallel & novel architecture — J Baird, ext 2041
Education and training — A Fenn, ext 1224

Marine Technology — BG Richardson, 071-321 0674

Teaching Company — Miss K Enifer, Faringdon (0367) 242822 ext 208

NUCLEAR PHYSICS DIVISION

Particle physics; studentships and fellowships — Miss C Armstrong, ext 1278
Nuclear structure — Miss JE Shepard, ext 1331
CERN — M Bowthorpe, ext 1271

SCIENCE DIVISION

Biological sciences — Dr SJ Milsom, ext 1136
Mathematics — Dr I Cameron, ext 1312
Neutron facilities — MJ Hotchkiss, ext 1222
Physics — Miss FE Smith, ext 1261
Science-based archaeology — Dr A Spalding, ext 1361
Chemistry — PD Tomsen, ext 1496
Synchrotron radiation facility; laser facility — Miss RL Sirey, ext 1061
Pharmacy; Science Board — Dr GLl Richards, ext 1323
Science Board — Dr ER Boston
Computing Committee — ext 1113
Education and training — E Sparkes, ext 1369

MATERIALS SCIENCE AND ENGINEERING COMMISSION

Ceramic and inorganic materials — Dr DA Ward, ext 1362
Metals and magnetic materials — AVR Emecz, ext 1110
Polymers and composites — D Cheyne, ext 1124
Medical engineering and sensors — Dr A Thomas, ext 1108
Semiconductors and superconductivity — Dr IM Scullion, ext 1338
Molecular electronics — Miss M Burke, ext 1124
Compound semi-conductor technology — PN Burnell, ext 1161
General enquiries — Mrs J Sullivan, ext 1435

FINANCE

Account queries (Swindon) — Mrs AB McKeown, ext 1434

RESEARCH GRANTS

Most enquiries should be addressed to the appropriate subject committee.
Terms and conditions; supply of forms — ext 1405

STUDENTSHIPS

Applications

Advanced course studentships. — ext 1414
Research studentships — ext 1030
Studentships tenable abroad, including NATO.
CASE — ext 1138
General enquiries — ext 1041

Current awards

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

FELLOWSHIPS

Postdoctoral (home, overseas, NATO); advanced and senior fellowships. — ext 1172/1403
Royal Society/SERC Industrial. — ext 1206/1352
CERN — ext 1057
ESA — 071-276 2438

Anglo-Australian fellowships:

Royal Observatory, Edinburgh 031-668 8100 — Mrs L Klimek, ext 267

Visiting fellowships on grants:

Enquiries should be made to the appropriate subject committee.

INTERNATIONAL COLLABORATION

Europe, Japan — ext 1036, 1315
ESF, rest of world — ext 1404, 2085
General — ext 1121, 1498
(For NATO fellowships and studentships tenable abroad, see under Studentships and Fellowships)
UK Research Councils' office in Brussels — Dr A Game, 010-322-230-5275

CENTRAL COMPUTING

Dr B W Davies, Rutherford Appleton Laboratory, Didcot (0235) 821900 ext 5547

INDUSTRIAL AFFAIRS UNIT

Dr R Burdett — ext 1173
LINK — A Medland, ext 1162

SERC BULLETIN — ext 1120
PRESS ENQUIRIES — ext 1257/1256

Wind turbine installed at RAL

The wind turbine installed at the Rutherford Appleton Laboratory's Wind Test Site in April 1990 is being used to investigate and develop an autonomous wind power system. Here short-term wind variability is compensated by the energy stored in a flywheel, and a diesel generator is brought into operation during low wind or calm conditions. This project, which will run for three years, is funded jointly by SERC, the Department of Trade and Industry, and three industrial companies and involves collaboration between scientists and engineers from Imperial College, London, Leicester University, RAL and the industrial consortium. It is described here by Jim Foster of RAL.

The horizontal axis wind turbine, supplied by Windharvester Ltd, has a 17-metre diameter rotor and a nominal power output of 45 kW at a wind speed of 12 to 14 metres per second, although the machine is designed so that it can be upgraded to 60 kW output for operation where the average wind speed is high.

The three rotor blades, made of epoxy composite, operate at a fixed pitch to avoid the complexity of a variable pitch control mechanism and are designed so that power is limited at high wind speeds by progressive stalling of the aerofoil surfaces. To prevent potentially dangerous overspeeding in high wind conditions, each blade is fitted with an automatically operated air brake which destroys aerodynamic lift and so limits the rotational speed; these are deployed, however, only in the event of a failure of both the primary and back-up braking systems.

The nacelle, containing the main shaft, gearbox, braking system, induction generator and yawing mechanism, is mounted at the top of a 15-metre high open lattice tower. Also in the nacelle are the safety monitoring devices, which are linked with the wind turbine control system so that the machine will automatically shut down in the event of a fault. At the rear of the nacelle is a fan tail assembly which provides power to turn the nacelle, through gearing, and maintain an accurate heading into wind.

It is possible for the output of the wind turbine to be connected into either the RAL local electricity grid or into the autonomous grid at the Wind Test Site.

Other major components of the experimental system at RAL include a pre-stressed laminated flywheel with an associated electronic variable speed drive, a 50 kW turbo-charged diesel generator with a sophisticated control system and dump load to dissipate excess energy, and a data acquisition and control unit.

The flywheel is designed to run at up to 6000 rpm in an evacuated enclosure and has an energy storage capacity of 10 megajoules (MJ), sufficient to maintain the average power load for up to five minutes.

Although the new wind turbine is primarily intended for use on the wind/diesel/flywheel project, academic researchers have already shown interest in using it for other projects, including the application of particle image velocimetry, fundamental aerodynamics and the study of yaw moments and cyclic blade loading.

The present and a previous autonomous wind diesel project have caused considerable interest internationally, and there are plans to build one and possibly several such systems on isolated Greek islands. Discussions are also under way with laboratories in India, China and the USSR with a view to building demonstration systems in those countries.

For information on the use of this wind turbine, or other wind turbines and facilities at the RAL Wind Test Site, contact Professor N H Lipman, Head of the Energy Research Unit at RAL.

J E Foster
Rutherford Appleton Laboratory

The new wind turbine at Rutherford Appleton Laboratory.