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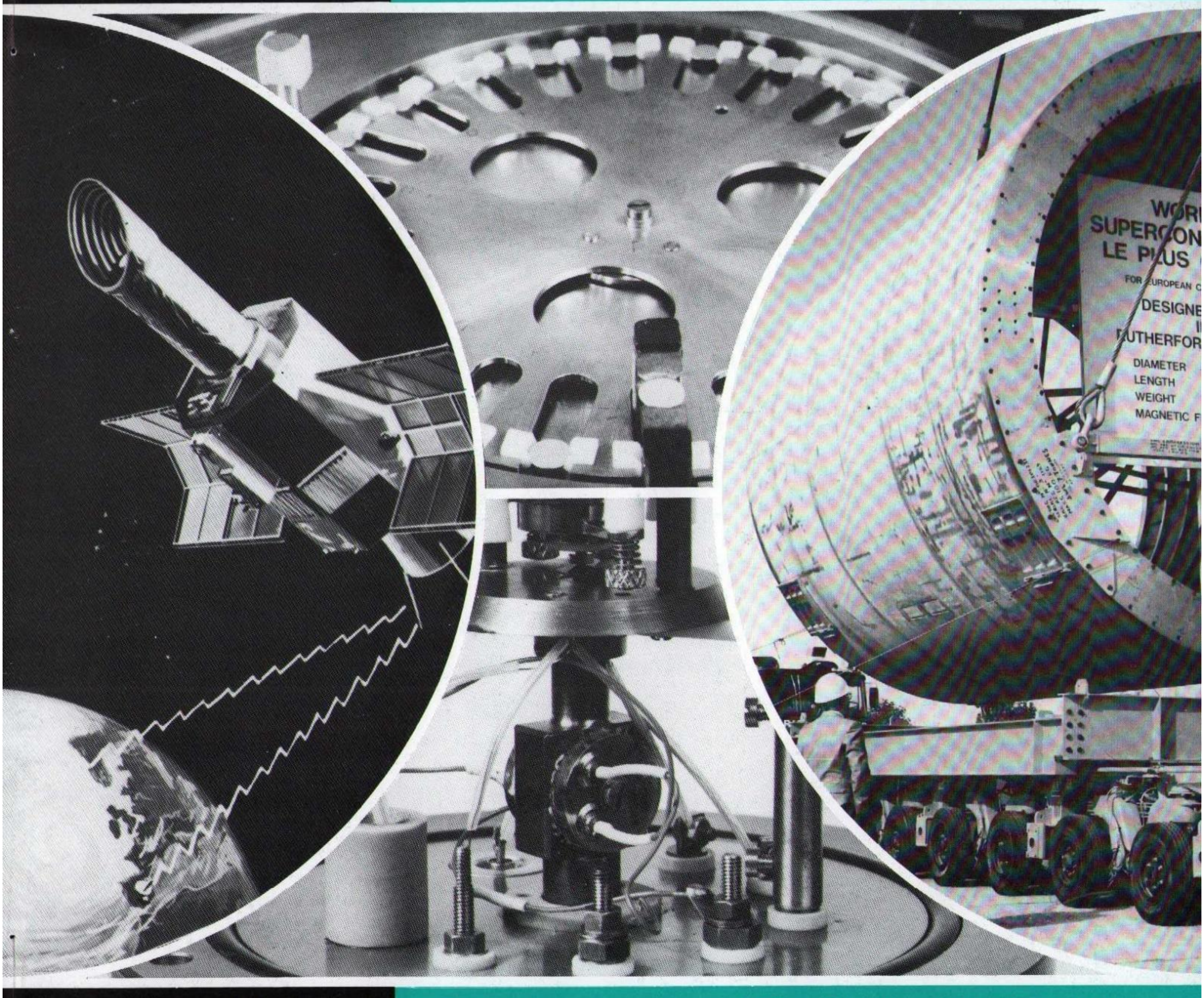

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The Science and Engineering Research Council is one of five research councils funded through the Department of Education and Science. Its primary purpose is to sustain standards of education and research in the universities and polytechnics through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

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

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Front cover pictures

Engineering large and small. Clockwise from the top: a prototype automated thermoluminescence reader (see page 27); the DELPHI solenoid en route from RAL to CERN (see page 6); a sample holder for high-field absorption and depolarisation experiments (see page 18); and an artist's impression of the International Ultraviolet Explorer in orbit 35,000 km from Earth (page 12).

Alan Michael Adye OBE (1927-1987)

Mike Adye

Mike Adye died on 21 October 1987 following a short illness. Mike was Director of Marine Technology in the Council from 1977 when the post was created until 1986 when the Marine Technology Directorate Ltd was formed. He became Director and Chief Executive of the new company which he established as a consortium of major companies in the offshore business and government agencies, including SERC.

In 1977 the Council's Marine Technology Task Force recommended the establishment of a Directorate to oversee the proposed new multidisciplinary research programme in this field. Shortly thereafter Mike was appointed Director, a position that he came to naturally from his wide earlier experience with BP in the construction of the Forties Field and other North Sea ventures. Indeed, his experiences with universities in the USA in the 1960s demonstrated to him how important it was to create a similar university community in the UK which was capable of meeting longer-term needs of industry.

In many ways MTD had to break new ground because of the wide disciplinary coverage involved, with the result that many of the lessons learned there have provided invaluable experience for the SERC Directorates that have followed.

Largely as a result of Mike Adye's dynamic leadership and balanced judgment, the new company, MTD Ltd, was formed with substantial extra industrial and government resources to ensure the continuation of the major programme in this area.

A J Egginton
Director, Engineering, SERC

Wealth from Science

The five Research Councils and the Patent Office sponsored a major conference on academic research and its commercial exploitation in the UK in November 1987, at the Queen Elizabeth II Conference Centre, Westminster.

The conference was opened by the Secretary of State for Education and Science, Mr Kenneth Baker, and the closing address was given by Mr Robert Jackson, Parliamentary Under Secretary of State at the department with special responsibility for higher education and science. Sir Francis Tombs, Chairman of the Advisory Council on Science and Technology chaired the morning sessions, and Professor Bill Mitchell, Chairman of SERC (in his capacity as Chairman of the Heads of Research Councils) chaired the afternoon session.

The speakers included Professor John Ashworth (Salford University), Dr John Bradfield (Cambridge University), Mr Tony Gray (Cogent Ltd), Professor John Cadogan (British Petroleum), Dr Charles DesForges (The Research Corporation Ltd), Mr John Fairclough (Chief Scientific Adviser, Cabinet Office), Mr Ian Harvey (British Technology Group).

The aim of the conference was to guide industry and the academic community in the successful exploitation and protection of intellectual property rights arising from university and polytechnic research.

Engineering Council

SERC was accepted as an Industrial Affiliate of the Engineering Council in 1987, in its capacity as a direct employer of professional engineering and technical staff.

As an industrial affiliate, SERC's views will be sought in formulating Engineering Council policies, particularly for the education and training of engineers and technicians, so that the quality of the academic courses and practical training is relevant to the needs of industry.

Council commentary

Council Commentary

In October, the Council held its annual 'policy meeting' as well as a normal business meeting, combining them with a visit to the Rutherford Appleton Laboratory.

The ABRC strategy document

Sir David Phillips, Chairman of the Advisory Board for the Research Councils, presented the ABRC's recently published document *A strategy for the science base* and answered questions. The Council supported the recommendations about the need to modify the financial rules under which research councils operate, especially in relation to annuality, and agreed on the importance of international collaborations both in big projects and in small science interactions. It especially approved the document's request that something be done to deal with the 'exchange rate problem'. Through its research grants to universities and polytechnics, Council was already highly selective and it did not believe that there was anything to be gained, but much to be lost, by a rigid designation of institutions as R, X or T. It was interested to note the ABRC's support for the concept of interdisciplinary research centres which the Council is already pursuing. Council decided to forward its views to the Secretary of State as part of the consultative process.

SERC and industry

The Council reviewed interactions with industry across the whole range of its activities, but concentrating on those schemes and methods that were designed to foster this collaboration. SERC has been at pains to monitor these schemes over the years but it has proved to be difficult to produce any quantitative measures of output. There is ample statistical evidence, however, that firms that participate once in, for example, the Cooperative Research Grants Scheme, are likely to do so again. The Council concluded that the schemes were working in the right direction and were valued by industry.

SERC manpower

SERC's payroll, at 2750, is much smaller than the number of research assistants and others supported by SERC research grants (over 8,000) or the number of SERC postgraduate students and fellows (about 10,000). It is however a considerable resource, and in some topics incorporates substantial parts of the national expertise. Although manning levels within the various programmes of the Council's four scientific establishments and at Central Office are approved annually, the Council wished to discuss more general questions relating to employment practice. A central point is the extent to which establishments contract work out: at one extreme, a laboratory might try to do everything in-house, with directly employed staff; at the other, the laboratory would become simply a contract-monitoring office. In the present financial circumstances, the Council is concerned to achieve here a balance that is effective scientifically and efficient in terms of budget.

The ESA science programme

Council considered its view of the mandatory science programme of the European Space Agency. The current excellent programme was agreed in 1984 at a level of funding which increased at 5% a year, reaching a plateau in 1989, after which no further increase had been authorised, although there have been suggestions that a further such increase would be sought by ESA. SERC is grateful that the additional funding over the 1984 level has been contributed by other departments. However, SERC does not place a further programme extension at sufficiently high priority, in relation to other demands, to warrant funding. The present programme, with level funding after 1989, provides a series of challenging scientific ventures — including the Hubble Space Telescope (jointly with NASA), the Hipparcos astrometry mission, the Ulysses solar mission, the Infrared Space Observatory and the first ESA cornerstone mission in solar-terrestrial physics. The Council was unable to recommend that a further increase in this programme should be supported.

University Research Centres

The Council received a progress report on the URC initiative. There had been an enormous response from academic institutions, with 72 applications received against the list of seven topics selected. *(Late note: Cambridge has been chosen as the first University Research Centre in Superconductivity).*

Intellectual property rights

The Council continued its discussion of the best means of dealing with intellectual property rights (ipr) arising from its collaborative grant-supported activities. It has decided to investigate whether it would be possible to deal with such rights in a manner similar to that used in the various research support schemes of the European Commission. This vests the rights in the partner with whom they originate, and incorporates a time-limit for exploitation that protects the interests of the other partner, whether industrial or academic. Pending the outcome of this investigation, the present arrangements will continue.

Royal Society/SERC Industrial Fellowships

The Council received a report on the operation of this jointly funded scheme from Sir Roger Elliott, chairman of its managing panel. The fellowships had enhanced collaboration between industry and the academic world over the years and Council agreed that the scheme should be continued.

Collaboration with Japan

In his report to the Council, the Chairman outlined the key points of his visit to Japan in August 1987 when he met senior representatives of government, research and academic institutes and industry. During the visit he signed a reaffirmation of the Aide-Memoire between SERC and Monbusho (Japan's Ministry of Education, Science and Culture). This recognised the strong scientific links between UK institutions of higher education and those universities and institutes in Japan supported by Monbusho, and identified a number of new topic areas, such as molecular electronics, low dimensional structures and muon scattering, for further collaboration. The Secretary of Council made a complementary visit to Japan in September and a highly successful meeting in biomedical materials was held in Japan at the end of October. A further meeting in biotechnology will be held in the UK later in the year.

Recent large grants

The following research grants, approved by Council at earlier meetings, have now received approval from DES:

Biotechnology research grants to Birmingham University and University College London for £1.67 million and £1.97 million respectively;

Research grant to Cambridge University for three-dimensional nanometre microelectronics for £1,384,000;

Consolidated research grant to Leicester University for X-ray astronomy and space instrumentation — up to £609,000 for one year;

Consolidated research grant to Cambridge University for support of the Mullard Radio Astronomy Observatory — up to £460,000 for one year;

Rolling grant to Sheffield University in support of the III-V Facility — £2,182,873 over four years.

Probes of the early Universe

Not only is the Universe expanding, but the detected limit of the Universe is also expanding. Twice during 1987 the size of the known Universe was increased through the discovery of a 'yet more distant' quasar. The light from these objects probably set off towards the Earth about 13 billion years ago when the Universe may have been 1 billion years old. Both quasars were discovered on photographic plates taken with the UK Schmidt Telescope in New South Wales, Australia; but, writes Dr David Morgan of the Royal Observatory, Edinburgh, they were found using completely different techniques.

The Plate Library at Edinburgh is the permanent home for plates taken with the UK Schmidt Telescope. Each of these 14×14-inch plates covers an area of sky 6.5×6.5 degrees and typically contains a quarter of a million star and galaxy images. The photographic database now stored in Edinburgh probably contains several billion astronomical images. Many of these plates are taken at the request of individual astronomers and are, initially, reserved for these astronomers' own use. However, they can be made available to other workers for special investigations.

The Plate Library is maintained as a working plate inspection environment for visiting astronomers and also acts as the coordinating facility for assessing and processing astronomers' requests for plates taken with the telescope. The value of having the entire plate collection located in one centre and maintained in an easily accessible form is seen in the fact that about half the photographic requests received at the Observatory are currently satisfied by loans of existing plates or copies made in the ROE Photolabs. The remainder need new plates taken with the telescope.

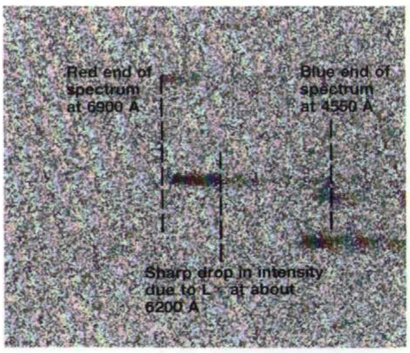
Quasars are widely believed to result from matter falling into black holes in the centres of galaxies and can radiate energy at a rate exceeding that from 100,000 billion stars similar to the Sun. However, they are so distant that on direct photographic plates they are indistinguishable from faint stars in our own Galaxy. Objective prism plates resolve the light from stars and quasars into short spectra which can reveal the stretching of the light-waves produced by the expansion of the Universe in the time taken for the light to travel to the Earth. Light that leaves a quasar in the ultraviolet part of the spectrum is consequently detected at the Earth at much longer wavelengths, often in the visual part of the spectrum. This stretching of the light waves, or redshift, is used by astronomers as a measure of quasar distances.

The first of the two 1987 quasars was found as part of a continuing search for bright, distant quasars by a team of astronomers from the University of Pittsburgh, USA, and the Institute of Astronomy, Cambridge. The leader of this team located the quasar on an objective prism plate held in the Plate Library of the Royal Observatory, Edinburgh, during a visit in August 1987. This particular plate was taken five years ago for a project concerned with peculiar blue dwarf galaxies and was proposed as a suitable plate for the quasar search by the Plate Library staff.

The redshift of the quasar, measured from the objective prism plate (see figure), was 4.1.

A further spectrum at higher resolution obtained with the Anglo-Australian Telescope gave a more accurate measurement of the redshift as 4.11.

This new quasar is important because it is four times brighter than the other quasars with redshifts above 4, thereby allowing the structure and composition of the early Universe to be studied in much greater detail than has been possible up to now. On its way to the Earth, the light from the quasar passes through many galaxies and clouds of gas, each of which leaves its 'imprint' on the light in the form of narrow absorption



The spectrum of the newly discovered quasar as it appears on the objective prism plate. It is characterised by a sharp change in brightness near 6200 Å. That feature, coupled with the fact that the spectrum appears uniform in brightness suggesting a blue or hot object, secured the identification as a high redshift quasar. (The spectra of normal stars increase significantly towards the red or long wavelength end.)

lines in the quasar spectrum. These are some of the features that will be studied in due course.

The second new quasar was discovered one month after the first and has the remarkably high redshift of 4.43. The technique used to discover the quasar was one of multi-colour photometry whereby direct photographs of the sky in different colours or wavebands are measured on a high-speed measuring machine, in this case the automatic plate-measuring machine at the Institute of Astronomy, Cambridge. The colours are then compared in a computer, using software that has been designed to select all objects that have peculiar colours and are unlikely to be normal stars or galaxies. Since this technique does not produce redshifts directly, the selected objects are then observed spectroscopically with a large telescope. Again the follow-up telescope was the Anglo-Australian Telescope. Although less useful as a probe of low luminosity matter in the early Universe, this quasar is important as the most distant of the small but increasing number of high redshift quasars. As with the first quasar, the primary data were the photographs provided by the Edinburgh Plate Library. Some of the plates used in this work were taken specially for the project, others were taken for other projects and loaned to Cambridge for this work.

The UK Schmidt Telescope is currently the most productive telescope in the field of high redshift quasar detection. Of the 14 quasars with redshift greater than 3.6, 10 have been discovered on material from this telescope, seven of them since January 1986. The techniques for detecting high redshift quasars are now becoming better established: objective prism plates covering large areas of sky provide the best means of detecting the rare bright quasars, while multi-colour photometry programmes, although needing more plates per field, yield more quasars to a fainter limit and are therefore better for probing more deeply into selected areas of sky. However, both methods rely on the large sky coverage of the plates taken with the UK Schmidt Telescope. Redshift 4 quasars escaped discovery for many years; it now remains to be seen how long the even more elusive redshift 5 quasars remain undiscovered — if they exist!

Dr David Morgan
UK Schmidt Telescope Unit
Royal Observatory, Edinburgh

The ZEUS experiment at HERA

Over the last twenty years, the great advances of our understanding of the nature of matter have been built on two experimental foundations — spectroscopy and dynamics, exemplified by the discovery of the J/ψ particle in electron-positron (e^+e^-) colliding beam experiments, and the finding of point-like quark structures within the proton in electron-proton (ep) collisions. This complementary approach continues with the construction of the Large Electron-Positron collider, LEP, at CERN (which will provide information on the neutral weak boson, Z°) and the Hadron Electron Ring Accelerator, HERA, at DESY, the Deutsches Elektronen Synchrotron, in Hamburg. HERA has a unique window on the structure of the proton, and on processes mediated by the charged weak boson, $W^{\pm}$. Dr David Saxon of Rutherford Appleton Laboratory describes one of the experiments being built to exploit this.

Excavation of the 6.3 km circumference tunnel under the DESY site and neighbouring parkland is now complete, and the first beams have been injected into it. The PETRA electron-positron ring, after eight years as the world's highest energy e^+e^- facility, has been converted into an e^+e^- booster to feed HERA, where 30 GeV electrons (or positrons) will collide head-on with 820 GeV protons in a ring of 450 superconducting magnets running at a 6 Tesla magnetic field at 4.2 K. Several countries are assisting in the development of the machine, including Britain. Physics interactions are expected in 1990.

Two collaborations, H1 and ZEUS, have been formed to build experiments with differing emphasis to study $e^{\pm}p$ collisions, with significant UK involvement in both. The scientists in ZEUS come from Bristol University, Imperial College of Science and Technology, Oxford University, Rutherford Appleton Laboratory (RAL) and University College London, together with physicists from Canada, Germany, Israel, Italy, Netherlands, Poland, Spain and the USA.

The apparatus is illustrated in the figure; 820 GeV protons are incident from the right and collide head on every 96 ns with an $e^{\pm}$ beam from the left. Typically, part of each proton fragment travels on down the beam pipe, and the rest is broken up and enters the detector. The left-right asymmetry of the detector reflects the very different electron and proton energies — the forward calorimeter needs to be twice as thick as the rear, and there is a large forward muon detector.

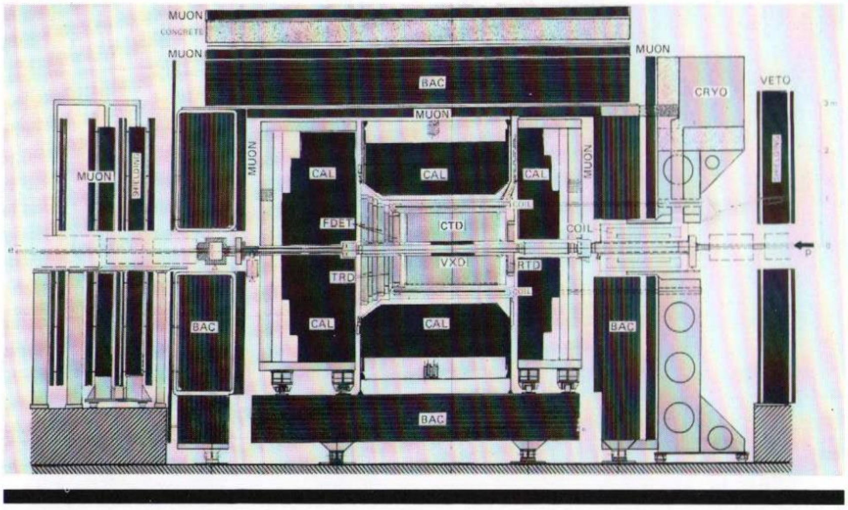
In order to make accurate measurements at momentum transfer of 30000 GeV^2 or so, the unique range of HERA, the calorimeter needs to have the best possible energy resolution. To this end extensive work has been done on 'compensating' calorimetry. Thin sheets of depleted uranium alternate with scintillator in a multilayer sandwich. In this set-up the random loss of energy due to nuclear binding energy (the source of degraded resolution in other experiments) is balanced by the energy released by spallation neutrons. This leads to outstandingly good resolution ($35\%/\sqrt{E}$ (E in GeV)) and an extension of the range of physics that can be measured. The calorimeters contain 500 tonnes of depleted uranium, enclosed in stainless steel jackets, and are backed up by an iron plate calorimeter all around to catch the tails of the energy deposits.

The British groups are responsible for the Central Tracking Detector (CTD) that lies at the heart of the apparatus in a solenoid giving a magnetic field of 1.8 Tesla. The field is significantly higher than at LEP experiments because of the higher energies of particles anticipated.

The CTD is a cylindrical drift chamber with nine superlayers, each with eight sense layers (72 in all). Track coordinates are measured (to some 100-micron accuracy) by the time of drift of ions to a sense wire, and four of the superlayers are arranged with small-angle stereo geometry to provide excellent measurement of the third coordinate. The planes of sense wires are located at 45° to the radius vector to compensate for the slewing of drift paths in the high magnetic field. Sophisticated design calculations are needed to balance electrostatic and magnetic influences. Because of the short inter-crossing time (96 ns) the maximum drift distance is kept small (2.56 cm). There are 4608 sense wires (30 μm tungsten-rhenium) and altogether 24,192 wires, each 205 cm long.

The electronics development by the UK groups breaks new ground. Both the trigger processors and the readout are constructed as logical pipelines. The chamber pulse-train for an individual event is five times longer than the beam crossing interval. The very high accelerator repetition rate (10.4 MHz) means that we must be ready for a new event even while testing the present crossing. The detector data moves in 9.6 ns steps down a 'digital pipeline', while a similarly constructed trigger processor delivers a 'keep/reject' decision after 1024 steps have been taken. HERA is unique among accelerators in having this high crossing rate, but these electronics developments are vital for future accelerators — the Large Hadron Collider proposed for CERN would have a crossing frequency of 40 MHz or more. The ZEUS-UK work is in the forefront of such electronic development. Information from the CTD is vital to reduce the trigger rate, and we are pursuing the use of coordinate information based on the time delay of signal propagation along a sense wire.

Dr David Saxon
Rutherford Appleton Laboratory



Vertical section through the detector. Protons enter from the right and electrons from the left. A thin solenoid (COIL) generating a magnetic field of 1.8 Tesla, surrounds the Central Tracking Detector (CTD). Hadron energy flow is measured in the depleted uranium calorimeter (CAL), backed up by an iron plate calorimeter (BAC). MUON detectors surround the detector. Specialist electron and proton forward taggers are out of sight left and right.

Progress on DELPHI at LEP

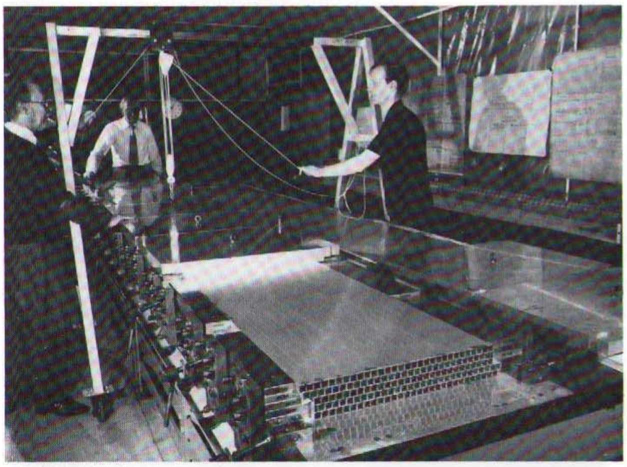
DELPHI is the acronym for the Detector for Lepton, Photon and Hadron Identification. Its purpose is to detect, identify and measure the products of the high energy collisions in LEP, the Large Electron-Positron collider currently under construction at CERN. DELPHI is being used in one of three LEP experiments in which British physicists will be taking part (see also *SERC Bulletin* Volume 3 Nos 7 and 8). Its design was described in *SERC Bulletin* Volume 3 No 1, January 1985. Dr Wilbur Venus of Rutherford Appleton Laboratory outlines progress on DELPHI.

The pace gets hotter as the start-up of LEP approaches. In the summer of 1989, at the bottom of four 100-metre deep pits distributed around the 27-kilometre circumference of the LEP ring, the four LEP detectors will record their first events. These will be the first examples seen in Europe of neutral intermediate vector Z bosons formed in perfect conditions for their detailed study — singly and at rest in the laboratory. Each detector will eventually study several million stationary Z decays. Each Z will have been created as the result of the head-on annihilation of a 47 GeV electron with a 47 GeV positron.

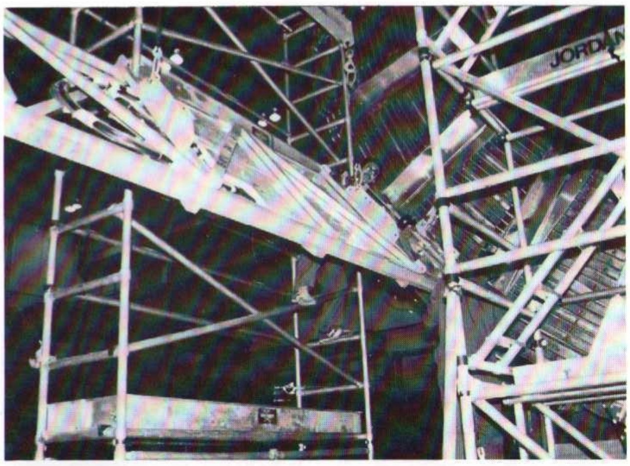
The Z was one of the major discoveries of recent times in particle physics. Its existence, partnering the already much-sought charged W boson, was first predicted by Glashow, Salam and Weinberg in the middle and late sixties, in the context of the epoch-making unification of the theories of weak and electromagnetic interactions. The prediction was at first confirmed only indirectly, initially by the observation of neutrinos inducing neutral current interactions (ie interactions mediated by the Z) in the Gargamelle bubble chamber at the CERN Proton Synchrotron in 1973; and then by the observation in 1974 of charmed quarks, which had been predicted by the same theory. The unambiguous production and decay of both Z and W particles was finally observed in the laboratory in the UA1 experiment at the CERN Super Proton Synchrotron in 1983. The successful prediction gained the researchers the Nobel prize in physics in 1979; the UA1 observation gained the Nobel prize in 1984. Finally in 1989 at LEP, the Z will become the main tool being used at CERN for probing even deeper into the structure of matter on the very smallest scale.

Will studying the Z in detail at LEP yield evidence of super-symmetry, the last and grandest symmetry of all? Or will it reveal evidence of the famed Higgs boson, the main source of mass in the Universe? We do not know, of course. But both super-symmetry ('SUSY') and the Higgs boson seem to be theoretical necessities. Both are fundamental to our present world view, and both are without a single shred of experimental evidence, as yet. But this was also true of Z and W bosons in their time, and the Z and W masses provide one of the most fundamental mass scales in the Universe so that our theories tell us that the Higgs and SUSY must also show up in the same neighbourhood, if ever. Or will the truth once again prove to be even stranger than our expectations?

Probably the most sophisticated of the LEP detectors will be the one that is currently being built by the DELPHI collaboration. Most of the Z particles will decay into a quark and antiquark together, perhaps, with one or more gluons. These are the fundamental constituents of strongly interacting particles (called 'hadrons'). As they move rapidly apart they will therefore not only form into fast hadrons themselves, but also radiate many other hadrons. The resulting events will be very complicated, containing on average some 20 charged hadrons in all, and 20 neutral particles. But among them may well be hidden the first signs of the Higgs boson or of SUSY, or perhaps of other, bigger, surprises. DELPHI has therefore been designed with an emphasis on high spatial granularity and direct extraction of three-dimensional space point information in order to be able to analyse as many as possible of them unambiguously and in detail. These hadronic events eventually need to be understood at the quark-gluon level. DELPHI will therefore contain powerful



Assembly in Liverpool of one of the 24 modules of the outer tracking detector. Each module is built of 147 aluminium tubes, 1.7 cm square and 4.7 metres long. Each tube carries a central anode wire. Ionisation produced by a passing charged particle drifts on to the anode. Measuring the time taken for the ionisation to drift measures the distance of the particle trajectory from the wire to better than 100 microns.



An Oxford team at CERN, mounting one of the last muon detector modules to go inside the iron yoke of the DELPHI magnet in CERN. It contains 14 chambers. The chambers work on the same principle as the outer detector tubes but the drift distance is typically 10 times larger. The chambers were built in Oxford and the modules assembled at RAL.

instruments for identifying the fast hadrons that will usually contain the primarily-produced quark pair. Principal among these instruments will be the Ring Image C(h)erenkov (RICH) detectors and, for detecting the presence of massive hadrons with very short lifetimes, the silicon-strip microvertex detector.

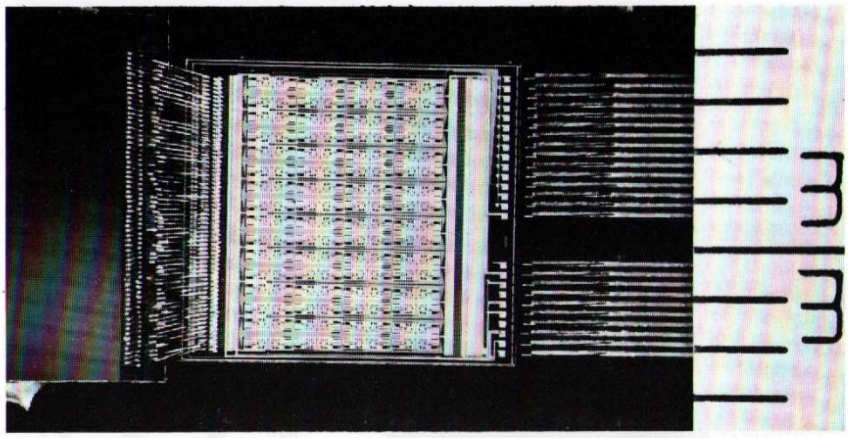
The collaboration building DELPHI consists of 35 institutes from Europe and the USA including three institutes from the UK (Liverpool, Oxford and Rutherford Appleton Laboratory). DELPHI is built in and around the largest superconducting solenoid ever constructed, 6.2 metres in diameter and 7.4 metres long, giving a 1.2 Tesla central magnetic field. The reason for making the solenoid so large is to enable it to contain not only the detectors that will track the charged particles, but also the electromagnetic calorimeters that will measure the electrons and photons, without the latter having to traverse the solenoid walls first. The UK is responsible for the hardware and software aspects of the solenoid, of the outer tracking detector (in collaboration with Paris), of the muon identifier (in collaboration with Brussels), of the microvertex detector (in collaboration with groups from Italy, CERN and Scandinavia), and of the on-line computer system (mainly in collaboration with CERN and Saclay).

Making good progress

The DELPHI detector will be located in Pit 8, the pit nearest to Geneva airport. Despite delays to the civil engineering work on the tunnel, due to a water-strike in the last difficult section beneath the Jura mountains, the pit should be available for installing the first items of experimental equipment on 15 April 1988 and the first events should be detected some 15 months later. Those 15 months will be a time of hectic but highly organised activity, as the many different detectors of which DELPHI consists are in turn installed, cabled, connected and tested in the restricted area at the bottom of the pit.

So far, things are going well. In particular, the items with UK involvement are well in hand. The superconducting solenoid has been constructed at RAL and transported to CERN. All of the 24 planks of the outer detector have been constructed in Liverpool, together with a number of spares, and tests show that the design performance will be largely exceeded. The muon identifier chambers are being constructed in Oxford and assembled into modules at RAL and many are already installed inside the iron yoke. The considerable technical challenges posed by the precise large-area silicon strip microvertex detector have been solved; in particular, the RAL electronics group have successfully developed a sufficiently low-mass, low-power amplifier+multiplex VLSI CMOS chip for reading out the 55,000 electronic channels that the detector contains. The hardware architecture of the on-line system has been defined, pieces are being acquired, and the software modules are being written. And increasing effort is now going into development of the various aspects of the off-line software.

Dr WAD Venus
Rutherford Appleton Laboratory



VLSI readout chip developed at RAL for the DELPHI silicon strip microvertex detector. Each individual 25-micron-wide silicon strip is connected by a 25-micron wire to its own low-noise, low-power charge sensitive amplifier. Each 6×6 mm square chip contains 128 amplifiers whose outputs are multiplexed and read out from the chip on a single twisted pair cable.

The fully assembled DELPHI solenoid being lowered on to its special trailer at RAL, ready for its journey to CERN.

Neutrinos from the supernova explosion

Two groups of elementary particle physicists have reported the epochal discovery of neutrinos from the supernova explosion SN 1987a in *Physics Review Letters* (6 April 1987). For the first time neutrinos that carry about 99% of the energy released in one of the biggest bangs since the Big Bang itself have been detected from a stellar collapse. Both experiments were initially set up to search for proton decay which was predicted to occur by the so-called Grand Unified Theories. Evidence for such decays remains elusive, ruling out the simplest versions of such theories. Thus, writes Dr Tegid Wyn Jones of University College London, the neutrino observations were an unexpected and welcome bonus.

Proton decay detectors

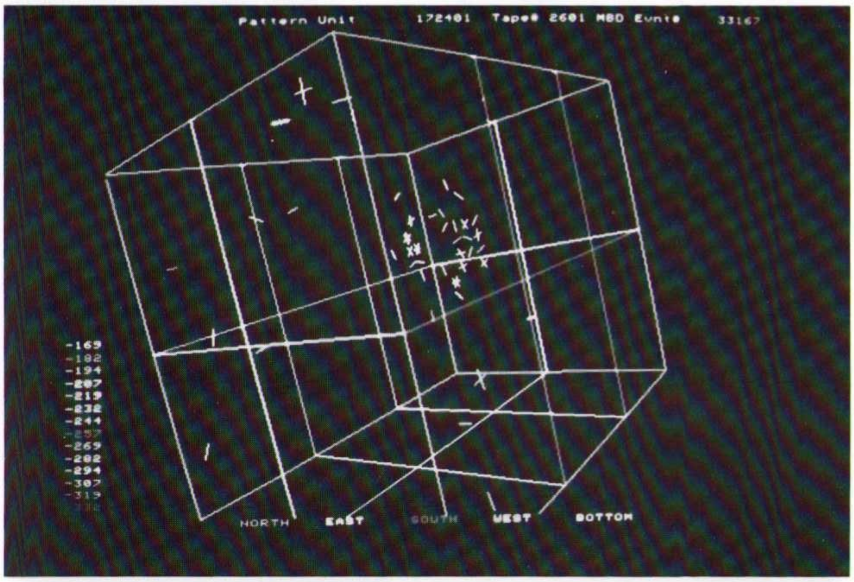
The detectors in the two experiments both contain large volumes of water and rely on the Cerenkov effect to detect particles traversing or originating in the water. Particles, which travel in water faster than the velocity of light in water, emit a shock wave of light in a cone about the direction of motion. Some of this light is detected by a phototube array at the boundaries of the detector. From the pulse heights, the relative timings and the pattern of the struck phototubes, it is possible to reconstruct the event vertex, and for simple events, the topology and track energies.

Atmospheric muons and neutrinos

Cosmic ray protons bombard the upper atmosphere producing pi and k mesons. These particles, and some of the daughter muons, decay to produce fluxes of muons and neutrinos at sea level. By going to greater and greater depths, the flux of muons diminishes, since the muon is charged and looses energy by ionisation. Thus the proton decay detectors were installed underground to avoid being overwhelmed by the muon flux.

The atmospheric neutrinos, whose energy ranges from about 100 to 3000 MeV, interact only weakly — at the rate of about half an event per kilotonne per day in water. An incoming electron neutrino can change into an electron with the virtual emission of the heavy mediator of the weak force (the W particle), which in turn is absorbed by a neutron in the water converting it into a proton in the simplest case. Antineutrinos on the other hand convert protons to neutrons in the simplest case. The electron and its neutrino comprise the first generation of the so-called lepton family of particles; two other other generations, namely the muon and tau generation, are known to exist.

Experiments must therefore reject the uninteresting muons and save the few atmospheric neutrino events, if for no other reason than to check that the apparatus and data reduction chains are working, and to save any other interesting events occurring in the detector.



Supernova neutrino event in the IMB detector. The straight lines show the detector walls. The crosses marking the hit phototubes show clearly the intersection of the Cerenkov light core from the positron, with the detector walls.

The Kamioka and IMB detectors

The Kamioka detector in Japan consists of 3000 tonnes of water, contained in an upright cylindrical steel vessel and viewed by 1000 twenty-inch Hammamatsu phototubes. This detector has an unrivalled photocathode coverage and can detect the Cerenkov rings of electrons down to 7 MeV. Largest of all proton decay detectors is the IMB detector located in a salt mine near Cleveland, Ohio, USA. This detector consists of a 7000-tonne visible volume of water contained in a nearly cubic cavity and viewed by 2048 phototubes. The low energy threshold for electrons is 20 MeV.

Neutrinos from stellar collapse

A 20 solar mass star is expected to evolve rapidly on the cosmic scale, with exothermic nuclear reactions successively converting light nuclei into heavier nuclei. These in turn are consumed to form still heavier nuclei, until a 1.5 solar mass iron core with a density of about 10^8 gcm^{-3} forms at the centre. No further exothermic reaction can take place to withstand gravity and the core collapses in less than a second, into a neutron star of density 10^{14} gcm^{-3} and radius about 10 km. During the collapse, electrons and protons in the core combine to form neutrons and neutrinos. The main neutrino emission, however, occurs when the enormous energy released in the collapse, some 3×10^{53} ergs, heats up the remnant to temperatures of 5×10^{10} K or 5 MeV. Under these extreme conditions of temperature and density, electron-positron pairs annihilate through the neutral mediator of the weak interaction (the Z° particle) to produce the three generations of neutrino-antineutrino pairs. In the core itself the density is so high that even the neutrinos are trapped by weak re-interaction processes. The neutrinos are radiated from the 'neutrino sphere' where the density has fallen to about 10^{11} gcm^{-3}, such that they can escape.

Neutrino detection in water

For the neutrino energy spectrum expected from the supernova (a 5 MeV thermal spectrum), the predominant detection reaction is expected to be that of an electron antineutrino converting a free proton in water into a neutron, the neutrino itself changing into a positron. (At these energies the protons in the oxygen nucleus are too tightly bound for this reaction to occur.) Since the proton is heavy, the positron is expected to be produced nearly isotropically in the detector. The Cerenkov thresholds at 7 and 20 MeV respectively suggest that it is events from the high energy tail of the thermal distribution that are detected as Cerenkov rings from the positrons in the two detectors.

All the neutrino species can also scatter off the atomic electrons in the water through the virtual exchange of the W and Z° particles. Although in these processes the emitted electron preserves the direction of the incoming neutrino better, it is expected to occur at only about 10% of the rate of the isotropic process at 10 MeV, and to decrease linearly with neutrino energy.

Observation of the neutrino signal

After Shelton, working at Las Companas Observatory, Chile, reported the optical sighting of the supernova explosion, several underground collaborations started to search their data for neutrinos events.

The Kamioka collaboration found 11 events in the energy range 7.5 to 36 MeV recorded on their tape in 12.44 sec at 7:35:35 UT±1 min on the 23 February 1987. The events appear to come in three bursts, the first burst of six events lasting 0.7 seconds is followed in 0.8 seconds by a second containing three events and lasting 0.4 second. Finally, seven seconds later, a third burst of three events lasting three seconds is reported. Two of these events are consistent with neutrino electron scattering.

At 7:35:41 UT±50 millisec, the IMB collaboration found eight events in six seconds in the energy range 20 to 35 MeV which possibly exhibit a two-burst structure. It is impossible to combine the two-event samples temporally because of the uncertainty in the Kamioka time but, taking into account the different energy thresholds and detection efficiencies, the data from the two experiments are in good agreement. From the corrected energy spectrum of the events, the energy released by the neutrinos is found to be in good agreement with the theoretical expectation of approximately 3×10^{53} ergs.

The Mont Blanc observations

The first group to claim a neutrino signal were the Liquid Scintillator Detector collaboration who operate a 90-tonne liquid scintillator detector under Mont Blanc. They attribute five events in the energy range 7 MeV or above to the supernova. Unfortunately, however, their signal occurred some 4 hours 40 minutes before the coincident observation described above. If two neutrino bursts had occurred, then the mean energy of the neutrinos in the first burst would have to be too low for detection in the water Cerenkov detectors. Since the LSD experiment is only 90 tonnes and the neutrino interaction probability falls as E_ν^2, the seven events observed lead to an embarrassingly large energy release in the supernova collapse. It has been suggested that the two well separated bursts could be explained by a first soft collapse into a neutron star, followed 4 hours 40 minutes later by a hard collapse into a black hole. Bearing in mind the energy problem of the LSD observations, and other difficulties, the suggestion has not won universal acceptance. Presumably in time it will be possible to find out what remains at the centre of the SN 1987a explosion.

Conclusions

Since the event samples are small, it is dangerous to draw too many conclusions, particularly concerning the short-term time structure and the angular distribution, from the data. Bearing in mind the LSD results as well, it is possible that the supernova explosion is more complicated than the simple understanding. Nevertheless the two coincident observations are in excellent agreement with the simplest expectation, where remarkably 99% of the enormous energy released in the collapse is converted into some 4×10^{58} weakly interacting neutrinos. Of these, 19 interacted in two large underground detectors some 170,000 years after the explosion!

Dr Tegid Wyn Jones
Department of Physics and Astronomy
University College London
(Member of IMB Collaboration)

A diver inside the water-filled IMB detector. He is attempting to line up the array of phototubes which hang down the wall. Each phototube is surrounded by a wavelength shifter plate.

Superconductivity Committee

A National Committee for Superconductivity has been formed by the Department of Trade and Industry and SERC. Chaired by **Sir Martin Wood** of Oxford Instruments, the Committee includes academic, industrial and government representatives. It will coordinate support for developments in superconductivity and advise both SERC and DTI on national research and development priorities in an effort to boost the UK field.

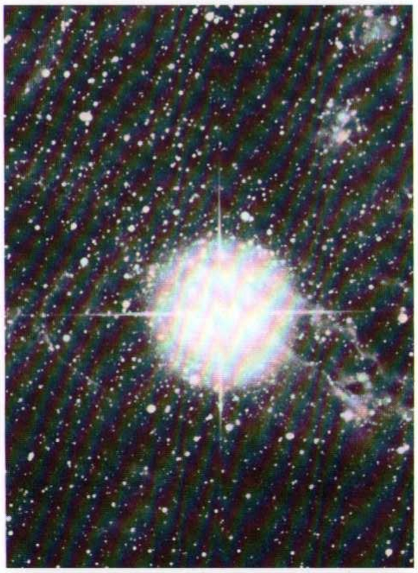
The DTI and SERC have also appointed **Dr Ian Corbett** as the UK's Joint Coordinator for Superconductivity. He is Head of the Applied Science Division at the Rutherford Appleton Laboratory, and his role will be to ensure that both industrial and academic interests are well informed about the policies of the National Committee for Superconductivity, and to keep in close touch with developments abroad.

Supernova studies by the Anglo-Australian Telescope

A supernova near enough to be seen by the naked eye occurs much less than once in a lifetime. Nevertheless, so much energy is released in each explosion that supernovae play a major if not dominant role in the dynamics of the gaseous component of the entire Galaxy. By releasing nuclearly processed material they also dominate the chemical evolution of stellar systems, being the probable source of most heavy elements seen in the Universe. Their extreme brightness makes them crucial 'standard candles' in the determination of the cosmic distance scale and rate of expansion of the Universe. For all these reasons, not to mention their intrinsic interest as the end-points of evolution for some types of stars and the origin of pulsars, it is not surprising that SN 1987a (the first supernova to be discovered in 1987) in the Large Magellanic Cloud has dominated the observing and instrumentation plans of the Anglo-Australian Telescope since it erupted late in February 1987, writes Dr Russell Cannon, Director of the Anglo-Australian Observatory. For the first time it is possible to turn the full power of modern telescopes and instrumentation to the detailed study of a supernova explosion; the AAT is playing a major part in this campaign, particularly in observations which require its full 3.9-metre aperture or some instrumentation unique in the Southern Hemisphere.

Since the AAT is heavily over-subscribed and scheduled several months in advance, switching to the supernova was not trivial. However the UK (PATT) and Australian time assignment committees immediately recognised the importance of SN 1987a and authorised a substantial amount of override; this combined with the use of most Directors' and Servicing Observing time, and the willing cooperation of most visiting observers, has meant that about 15% of the total time has been devoted to the supernova since it exploded.

The first problem was to determine, by comparison with previously taken photographs, which star actually had exploded. A plate taken a few days after the explosion was carefully measured by Graeme White (CSIRO Division of Radiophysics) and showed that SN 1987a coincided with an unremarkable blue supergiant star known as Sk-69° 202, from a list of such stars compiled by Sanduleak. This caused two problems initially. Supernovae were generally supposed to occur in red supergiants, not blue, although this was a purely theoretical prediction since no progenitor had ever before been seen; secondly it was reported that Sk-69° 202 was still visible in ultraviolet spectra taken with the International Ultraviolet Explorer (IUE) satellite. The first of these problems was resolved with the realisation that massive stars can evolve reasonably easily from red to blue (ie cool to hot) depending on details such as the rate of mass loss, while subsequent careful analysis of the IUE data showed that the ultraviolet emission was coming from two other hot supergiants, probably companions to Sk-69° 202.



The supernova seen on the right, blazing forth in the Large Magellanic Cloud, had been recorded three years before it erupted, as shown on the left. Both photographs were taken using the Anglo-Australian Telescope.

The spectrum of the supernova is essentially that of an enormous and rapidly expanding shell of hot gas, and can be well studied with small telescopes; indeed with the AAT the light of the supernova has to be spread out or attenuated in some way to avoid damaging the sensitive detectors normally used on much fainter stars. However, much additional information can be gained by observing the spectrum in polarised light, using the unique Pockels cell built by the Royal Observatory, Edinburgh, for the AAT. If the supernova were expanding with spherical symmetry, no polarisation variations would be seen; however, any ellipticity, lumpiness or jet structure is likely to produce polarisation changing with wavelength. Such variations are being seen at quite high levels, and they change with time, somewhat to the embarrassment of theoreticians who started with simple spherical models. To model all the structure seen is obviously going to be a long slow job; for the time being, the objective at the AAT is to obtain as many data as possible while the supernova is bright and evolving rapidly.

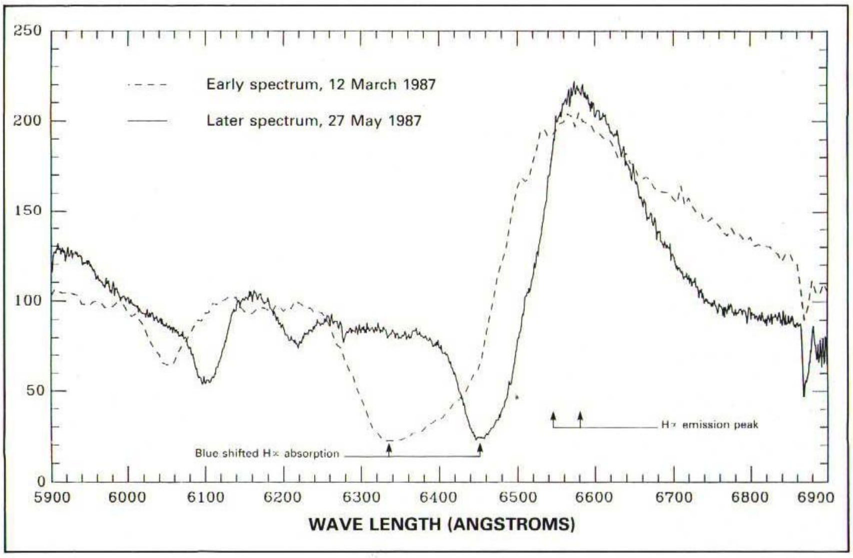
The structure of the supernova can also be probed using speckle imaging techniques, to try to attain the AAT diffraction limit of about a thirtieth of a second of arc, rather than the limit of around one second of arc normally set by atmospheric 'seeing'. Early hopes of measuring the diameter of SN 1987a soon evaporated when it was realised that this was an unusually small supernova; however some data had already been taken by a team from Imperial College of Science and Technology, led by Peter Meikle and Brian Morgan, and once again the supernova produced a surprise in that some structure was seen. It appears that SN 1987a may have a transient secondary component separated by less than a tenth of a second of arc, but more data are being obtained at the AAT and elsewhere. Speckle observations may also yield a measurement of the 'light echo' from the original explosion and hence give an independent distance estimate to the object.

One very important and more easily interpreted type of observation concerns the interstellar matter between the sun and the supernova. Bright nearby stars often show weak absorption lines due to elements such as sodium and calcium in gas clouds along the line of sight. Distant quasars have yielded similar information on gas in other galaxies, but only at low resolution. SN 1987a for the first time permits detailed study of many separate clouds and cloudlets in our Galaxy, the Large Magellanic Cloud and even in intergalactic space between these two galaxies. At least two dozen separate clouds can be identified. At the AAT a particular effort has been made to exploit the brightness of the supernova to look for atomic lines which are normally much too weak to be detected. Max Pettini and his colleagues have reported the first ever detection of absorption due to highly ionised iron [FeX] in the Large Magellanic Cloud, indicating the presence of gas with temperatures in excess of a million degrees.

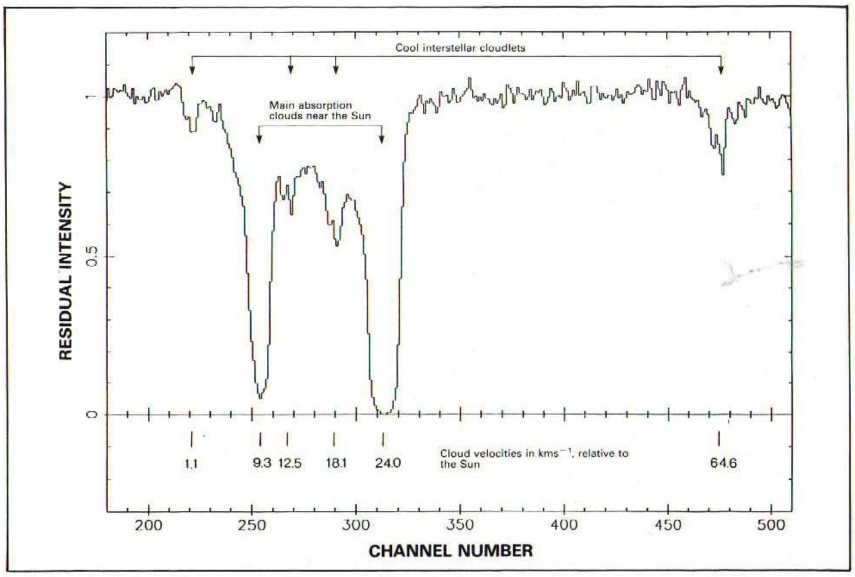
At the other extreme, a specially built, extremely high dispersion spectrograph has yielded evidence for very cool, quiescent clouds as well. Peter Gillingham, an engineer who is Officer-in-Charge of the AAT at Siding Spring, realised that he could build a spectrograph with ten times higher resolution than usual, using a mixture of borrowed and hastily made-up components. This 'string and sealing wax' instrument succeeded beyond our most optimistic predictions, producing spectra of unprecedented quality in which the hyperfine lines of sodium were clearly resolved in several clouds. This is another astronomical 'first' for the AAT, indicating that these intergalactic clouds have temperatures less than 170 K and extraordinarily low turbulent velocities of at most 0.2 kms^{-1}.

These are just some of the early highlights from AAT observations of SN 1987a. Obviously this is going to be a prime observational target for years and indeed decades to come. Already the data have produced an explosion in our knowledge and understanding of supernovae, as well as quite a number of surprises. However, despite having put a lot of effort into the supernova and having had some successes, there is always the uneasy feeling that the AAO is not doing enough. Since it may be centuries before another supernova of comparable brightness is observed from earth, one can argue that astronomers would be well advised to devote *all* the time on *all* their telescopes to collecting data with every conceivable instrument and at all accessible wavelengths, while they have the opportunity. Even doing this, it would be difficult to avoid the situation where in a few years' time astronomers and astrophysicists, having analysed the available data and with the benefit of hindsight, will ask why on earth the observers did not make other crucial observations when they had the chance, back in 1987. At the moment nobody knows what apparently insignificant blip in a spectrum may turn out to be of enormous significance, or how frequently the supernova must be observed to give full coverage of its evolution. Even at the present level of activity there is no time to assimilate the data from one night before planning observations for the next. However, the best that can be done is to observe the supernova in as many ways as astronomers can think of, in the case of the AAT concentrating on really high quality data which depend on collecting as many photons as possible. We can only hope that our successors' frustration at our lack of effort and imagination will be tempered at least by gratitude for those data which we are bequeathing to them.

Dr Russell Cannon
Director, Anglo-Australian Observatory
New South Wales



Spectra of SN1987a taken three weeks and three months after the explosion. The main feature in the region shown is the red Balmer alpha line due to hydrogen atoma. It has the characteristic 'P Cygni' shape due to a rapidly expanding shell of gas, with a broad emission peak and a Doppler blue-shifted absorbtion trough, with expansion velocities of 20,000 kms^{-1} initially, falling to 10,000 kms^{-1} later.



A small part of a very high resolution spectrum taken with a special spectrograph on the AAT. It shows absorbtion by sodium atoms in several interstellar clouds. The fine structure seen in the weaker lines indicates that some of these clouds are surprisingly cool and have remarkably low internal turbulence.

IUE — ten years of ultraviolet exploration

All being well, the publication of this article will coincide with a remarkable event in the annals of astronomy — the tenth anniversary of the launch of the International Ultraviolet Explorer (IUE), without doubt the most productive astronomy satellite to date. The brainchild of Professor Robert Wilson of University College London, IUE had a gestation period of well over a decade before it was carried into orbit on a Delta rocket on 26 January 1978, from where it has served the astronomical communities of Europe and the USA famously ever since. Dr David Stickland of Rutherford Appleton Laboratory pays tribute to this outstanding workhorse.

First, let us recap on what IUE is and what it does. Orbiting in an elliptical geosynchronous path over Central America (in constant view of the NASA tracking station), IUE carries a modest 18-inch telescope which feeds light to two spectrographs covering the wavelength ranges 1150Å to 2000Å and 1950Å to 3300Å. This light is then dispersed either into a low-resolution spectrum (suitable for faint objects) or into a high resolution echelle spectrum, which is recorded by the vidicon cameras contributed to the project by the UK. The pointing of the spacecraft and the operation of the scientific instrument are fully interactive and are controlled from the ground all the time — from the Goddard Space Flight Center for 16 hours a day and from the European Space Agency station at Villafranca near Madrid for the remainder.

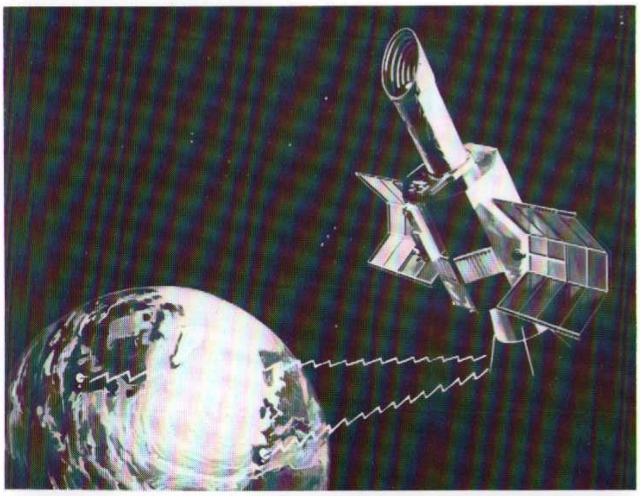
Several factors have contributed to IUE's success story. First, the longevity of the satellite: designed for a three-year mission, the scientific instrument is still working well after ten and this has enabled the collection of a vast harvest of data, all of which are made available to the whole community just six months after the observations are secured. Secondly, the ultraviolet part of the spectrum is generally dominated by astrophysical processes similar to those which operate in the optical region, the traditional training ground for astronomers, and so there was a wealth of expertise waiting to be brought to bear. Thirdly, but by no means least, the mode of operation of IUE is similar to that of a ground-based telescope (but with some important advantages, such as the cloudless 24 hour nights) so that the astronomer visits the ground station and directs his observations, making real-time decisions on the basis of incoming data. Moreover, he leaves the station with data ready to exploit without the need for a major effort of reduction back at his home institute. It has also been important that IUE has operated a schedule with essentially *all* the time going to guest observers. These last two points surely make it a model for future missions.

There can be few areas of astrophysics which have not benefited greatly from studies using IUE, as attested by the range of topics covered in the recently published book *Exploring the Universe with the IUE Satellite* (ed Y Kondo, Reidel, 1987). With the exception of the Sun (whose light would damage the instrument) and Mercury (which always hovers too close to the Sun), almost everything in the Universe has been fair game for astronomers awarded time.

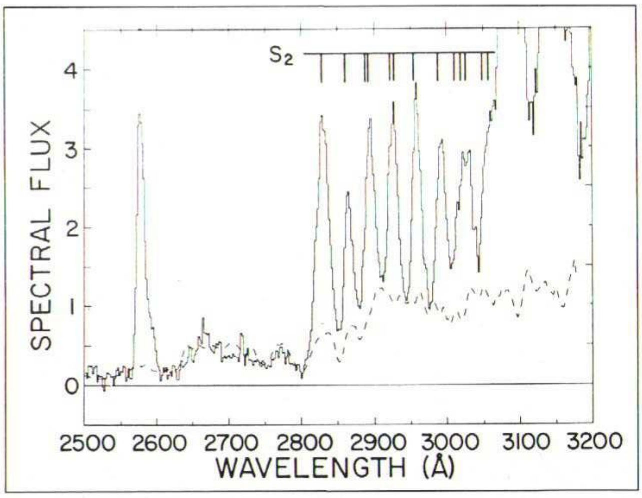
Close to home, all manner of bodies in the Solar System have been under scrutiny. Their primary source of light is radiation from the Sun but if they have atmospheres, then the atoms and molecules in the gas impart additional features to the spectrum of the reflected light, giving clues to the composition, physical state and energy balance of those atmospheres. If the bodies are too small to hold on to an atmosphere, then we receive back information on the reflectivity (or albedo), putting constraints on the chemistry of the surface; in this way, the Gallilean satellites of Jupiter have been shown to have a covering of water ice contaminated with sulphur compounds. Many comets too have been followed with IUE, and a variety of atomic and molecular emission lines observed as the 'dirty snowballs' approach the Sun. When close enough, their outer coats sublime away into space where the gases are set glowing in the fierce ultraviolet rays from our star.

Turning to deeper space, much time has been devoted to star watching. The hottest stars emit most of their energy in the part of the spectrum quite inaccessible from the ground and IUE has thrown important new light on the temperatures of these, often massive, objects. But such stars not only pour electromagnetic radiation into space — they also shoot out quantities of matter. The spectroscopic hallmark of this process is the so-called 'P Cygni' profile, shown by strong lines of several prominent atomic species, and it leads to the conclusion that the evolution of such stars can be markedly affected by mass loss.

Nor are cooler stars (like our Sun) dull in the ultraviolet, although they radiate



Artist's impression of the International Ultraviolet Explorer in orbit 35,000 km from Earth.



The ultraviolet spectrum of the nucleus of Comet IRAS-Araki-Alcock near the time of closest approach to Earth showing the sulphur emission bands discovered with IUE.

mainly in the optical and infrared parts of the spectrum. Above the surface, the temperature structure undergoes an inversion, rising up through the chromosphere and transition region to reach millions of degrees in the corona. Admittedly the gas is thinner here but an exotic range of processes go on to produce a wealth of emission-line features in the ultraviolet spectrum which can be used as diagnostic tools for assessing the state of this plasma.

Observations of binary stars are often fascinating, especially when the two components are interacting. One example is the Zeta Aurigae system in which a bloated cool star is orbited by a much smaller and hotter one; the red star is gently losing mass in a wind that sweeps over its blue companion, which retaliates by exciting the the surrounding gas (producing a beautiful spectrum of emission lines) and collecting a wake of material behind it. Among binaries, all sorts of combinations and permutations exist, many of which are variable and some of them violently so. A key feature of IUE operation is its flexibility and rapid response to such unpredictable events, called 'targets of opportunity', and many such happenings have been observed to the great benefit of our understanding of the underlying physical processes. When a dense white dwarf star tires of its less-evolved companion dumping material on its surface, it blows up in a runaway nuclear explosion called a nova (or new star, since it may brighten suddenly into visibility). Even more spectacular are supernovae, and IUE astronomers were in the vanguard studying what may turn out to be the astronomical event of the century — the supernova which brightened to naked-eye visibility at the end of February 1987 in the Large Magellanic Cloud (see page 10).

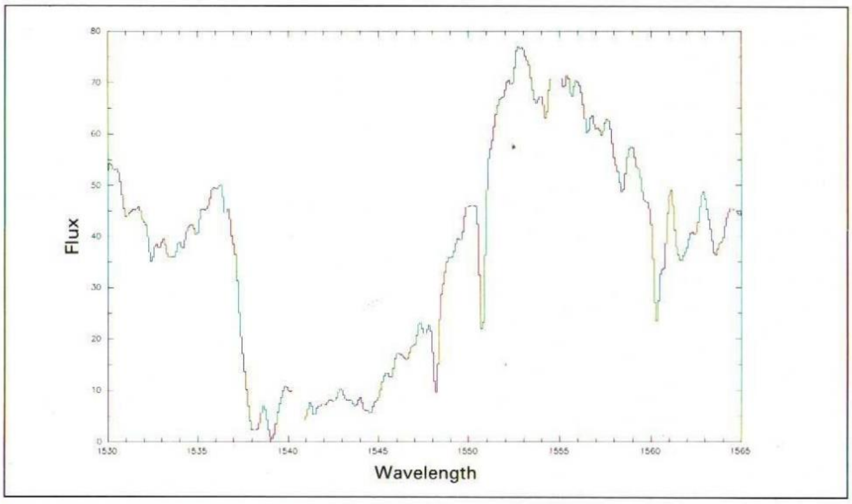
IUE has played an important role in two further areas. The first is study of the interstellar medium, the almost vacuum-thin filling of gas and dust between the stars and from which the stars and planets formed. Using the supernova as a bright background light, the rich pattern of absorptions in its spectrum, due to atoms and ions in the massive cold clouds along the line of sight, tells of the distribution of matter in space and of its composition. Many such studies have been made, using stars in our Milky Way Galaxy and both stars and whole galaxies beyond as background sources.

The other point is that observations have not been confined to the Milky Way. The IUE is so sensitive that numerous individual objects in nearby galaxies have been observed (some even at high resolution) leading to progress in comparing these other systems with our Galaxy. Pushing the frontiers back further still, IUE has observed hundreds of galaxies, or at least their centres, where highly energetic events are taking place, involving, perhaps, the accretion of matter on to massive black holes. Studies of quasars and active galactic nuclei, combining results across the whole electromagnetic spectrum, are advancing towards an understanding of the power sources of these cosmological beacons. In turn, this will enable us to probe the furthest reaches of space, looking back in time towards the beginning of the Universe.

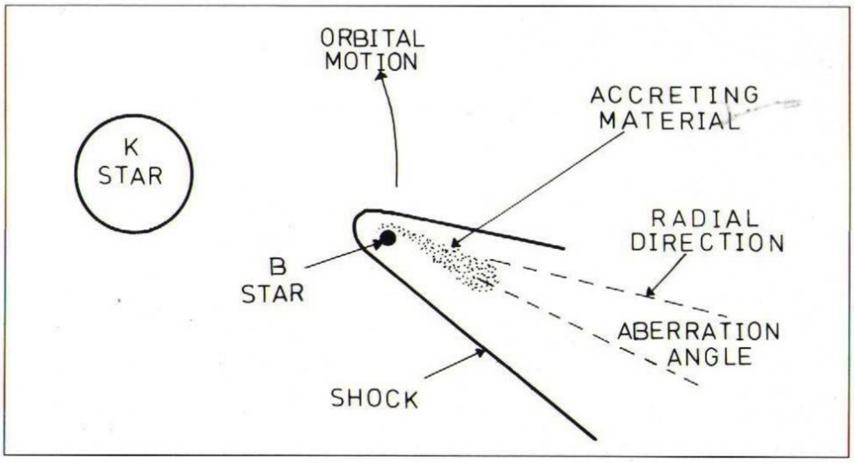
What is the future for IUE? Barring a catastrophic failure of a vital component, the outlook is good for some time yet, as the sensitivity of the scientific instrument has decreased by only a few percent over ten years. The inexorable decay of the solar arrays will eventually call a halt when there is insufficient power for any kind of fruitful operation, but this could be well into the next decade. The NASA engineers, who have nursed IUE through a few crises — including the loss of four of its six gyros — have one or two tricks up their sleeves yet. A one-gyro system is not far from readiness and a zero-gyro mode is a possibility.

Already IUE has accumulated some 60,000 images and continues to collect about 6000 more each year. These are all deposited in the archives of the three agencies responsible for the project — NASA, ESA and SERC — to be made freely available for research. In the UK, this task is handled at Rutherford Appleton Laboratory and each year some 2500 images are distributed on tape for analysis on the STARLINK computers; the other agencies report similar demands. This has resulted in more than 1400 papers published in the main journals of astronomy as a direct result of IUE observations; many more have been published in other journals and in conference proceedings — indeed, eight conferences dedicated to IUE have been held, the most recent at University College London in 1986 attended by 200 astronomers. The next is scheduled for April 1988 at Goddard Space Flight Center to celebrate 10 years of guest observer operation.

Dr D J Stickland
Rutherford Appleton Laboratory



The prominent absorption feature due to three-times ionised carbon in the spectrum of the hot, massive star AO Cassiopeiae originates in the strong wind which may carry off 10^{21} tons of matter every year.



A schematic model of the Zeta Aurigae binary system derived largely from IUE observations of the interaction between the hot B-type star and gas from the cool K-type star.

Strategy of the Electro Mechanical Engineering Committee

The Electro Mechanical Engineering Committee (formerly the Machines and Power Committee) has recently reviewed its overall policy with a view to developing a more cohesive overall strategy which can best aid national wealth creation.

The Electro Mechanical Engineering Committee is part of the Engineering Board of the SERC and has responsibility for supporting research and providing trained manpower for a wide section of industries. Its remit covers mechanical, electrical, aeronautical and nuclear engineering, and its industrial scope includes ground transport, aerospace, machinery, electricity generation and supply, and electrical equipment.

Various studies were undertaken from which the Committee concluded that a change in direction of research was necessary: the emphasis should move from work primarily proposed on the basis of academic interest to that which has a more balanced style and identifies more closely with industry, and translates fundamental knowledge into design. This would often mean taking a more multidisciplinary approach and crossing boundaries between various subject areas.

Such a strategy clearly demands that the Committee, Subcommittees, industry and academic researchers all play a much more active role in defining areas where research is required. As a step towards this, the Committee has restructured its Subcommittees so that they are now oriented towards coherent industrial sectors instead of towards academic disciplines.

Electro Mechanical Engineering Committee

Electrical and Power Industries Subcommittee	**Machinery, Plant and Vehicle Industries Subcommittee**	**Aerospace Industries Subcommittee**
covering SIC codes:	covering SIC codes:	covering SIC codes:
1610 - production and distribution of electricity 34 - electrical and electronic engineering	32 - mechanical engineering and process plant and control equipment 33 - office machinery and data processing 35 - motor vehicles 36 - (except 364) - other transport	364 - aerospace equipment, systems manufacturing and repairing
Also responsible for CEGB Cofunded Programme	Also responsible for SPP in the Design of High Speed Machinery	Also responsible for Rolls-Royce Cofunded Programme

The new Subcommittee structure

The three Subcommittees are in the process of developing a more detailed strategy for the areas for which they are responsible.

The contact points for various areas are:

SPP in Design of High Speed Machinery
Dr G Sweeney
(telephone Macclesfield (0625) 72623)

Rolls-Royce Cofunded Programme
Mr L Airey
(telephone Farnborough (0252) 541989)

CEGB Cofunded Programme
Dr J Andrews
(telephone Southampton (0703) 663232)

Integrated Drive Systems Initiative
Professor P J Lawrenson
(telephone Leeds (0532) 443844)

Electrical Power Systems Initiative
Professor M J H Sterling
(telephone 091-374 3920)

SERC Enquiry Points at Central Office, Swindon
Electro Mechanical Engineering Committee
— Ms Carol Iddon (ext 2103)

Aerospace Industries Subcommittee
— Mr Nigel Birch (ext 2103)

Electrical and Power Industries Subcommittee
— Mr Charles Whitlock (ext 2350)

Machinery, Plant and Vehicle Industries Subcomittee
— Miss Philippa Rogers (ext 2117)

A leaflet setting out the strategy of the Committee in more detail has been produced and was widely distributed to the community. Extra copies may be obtained from Mrs Maureen Wilkes, SERC Central Office, ext 2201.

Joint SERC-CEGB announcement

SERC and the Central Electricity Generating Board signed an agreement in November 1987 to extend a four-year engineering research programme for a further three years and to boost the amount spent on research projects by an additional £1.3 million. Funding of the programme is to be increased from £242,000 a year to £350,000 in 1988 and £500,000 a year for the following two years.

SERC and the CEGB will each contribute half the cost of the programme, which provides a number of grants to universities throughout the country undertaking high-quality academic research relevant to the work of the CEGB.

Four areas have been earmarked as priority projects. These are:

- Electrical systems and control engineering;
- Computational fluid dynamics;
- Predictive techniques for materials failure; and
- Non-destructive testing.

The programme will continue to be monitored by a panel made up of three representatives of the CEGB and the three members nominated by SERC.

Flood channel facility

The Flood Channel Facility, which was constructed at Hydraulics Research Ltd, Wallingford, and officially opened by Sir Alan Muir Wood FRS in April 1986, represents a major initiative and investment made under the Engineering Board's Civil Engineering Programme. The total capital cost of just over £1 million (including five years' running costs) has been met by SERC (£600,000) and by HRL (£470,000). In addition, SERC has already awarded more than £300,000 of research grants, which are supplemented by further contributions from HRL, and from the Ministry of Agriculture, Fisheries and Food and Thames Water Authority. The facility is described here by Donald Knight of Birmingham University.

The facility consists of a 56-metre long by 10-metre wide flood channel with a discharge capacity of 1.1 m^3/s, and is being used to investigate the complex interaction between flows in a river channel and over a floodplain. The size of the channel makes it possible to reproduce flows representative of those that occur in natural rivers — that is, those that are strongly three-dimensional in character with large lateral transfer of momentum between the floodplain and the main channel.

The prime reason for constructing the facility is that current knowledge of flow in compound channels is inadequate. A compound channel comprises a deep section — a main river channel or tidal channel at low water — flanked on one or both sides by an area of shallower flow which may be inundated only occasionally. Such channels feature in many flood alleviation schemes either by excavating a flood berm alongside the river channel or by the construction of flood protection embankments. Compound channels are also becoming increasingly attractive as an environmentally satisfactory solution to the often conflicting requirements of greater conveyance capacity and preservation of wetland habitats.

Existing research channels were too small for experiments in which the full width of the flood plain and the sinuosity of the main channel are to be studied. It was therefore decided to provide a central facility, rather than a limited number of local channels, which would be available to all researchers and which would encourage cooperation between researchers and also with practising engineers.

The facility

The facility comprises a tank constructed of 1-metre high plates with the base moulded in cement mortar to the required geometry. The length of the flume may be considered in three parts: an upstream entry length of 25 metres, a 15-metre test section, followed by the lead-out section to the tail gate controls. In the test section there are pressure tappings every metre along the bed of the channel leading to stilling pots and gauges to measure water level to ±0.1 mm. The discharge is provided by six pumps whose rated capacity varies from 0.057 to 0.57 m^3/s. This allows the flow to be controlled within ±2% over the range 0.01 m^3/s to the full capacity of 1.08 m^3/s.

Although traditional instrumentation, such as miniature current meters, electromagnetic flow meters and Preston tubes, is available, the facility is also equipped with a sophisticated laser anemometry system to measure the turbulent flow velocities. The laser anemometer has a miniaturised optical head which is a cylinder 15 mm diameter by 100 mm long. This is coupled by a 20-metre long armoured fibre-optic cable to the laser and transmission optics. The probe-head may therefore be placed anywhere in the test area, with the laser itself mounted at the side of the facility. The probe senses two velocity components simultaneously in the plane normal to the axis of the probe-head and thus produces sufficient information to calculate the turbulent Reynolds stresses. It is only now, with the advent of laser anemometry and the exploitation of fibre-optic technology, that experimental data can be conveniently gathered to validate turbulence models on the scale of the flood channel facility.

The data from all the instruments is logged and processed by a PDP micro 11/73 computer installed in an office beside the facility.

The research programme

A programme of research has been formulated by seven university research teams and practising engineers. The initial programme of experimental work involves teams from Birmingham, Bristol, London (Queen Mary College) and Ulster Universities. Following fundamental studies of shear layers in straight prismatic channels including those with skewed floodplain banks, a series of tests is planned on meandering channels of varying sinuosity. It is also proposed to undertake a set of loose boundary experiments to study certain aspects of sediment movement. Field studies on the rivers Roding (Essex), Main (Ulster) and Dee (Aberdeen) are also being undertaken to investigate certain features at full scale.

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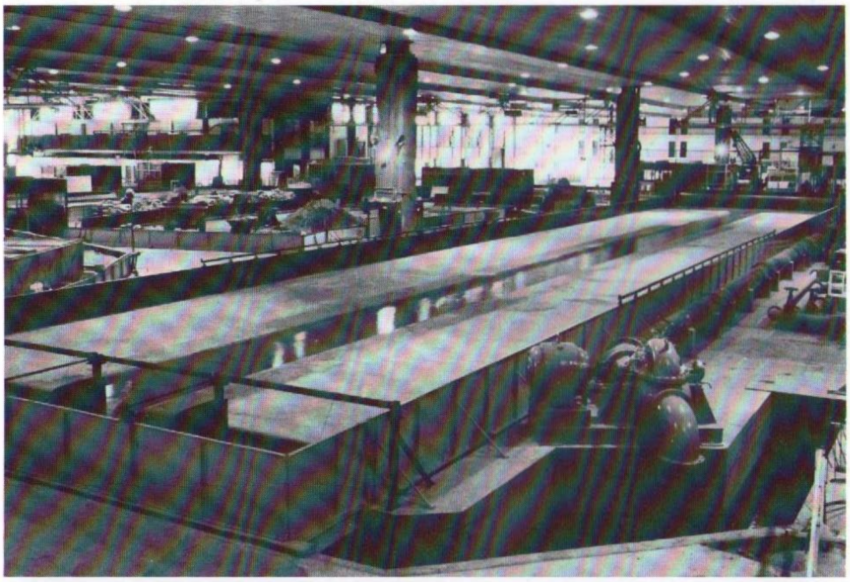


View of the SERC Flood Channel Facility at Hydraulics Research Ltd. The tank is 56 metres long, 10 metres wide and 1 metre deep with a base moulded in cement mortar to the required geometry.

CASE studies

Distribution of CASE studentships by subject area

By 1 April 1987, a total of 891 CASE studentships had been taken up for the 1986-87 session

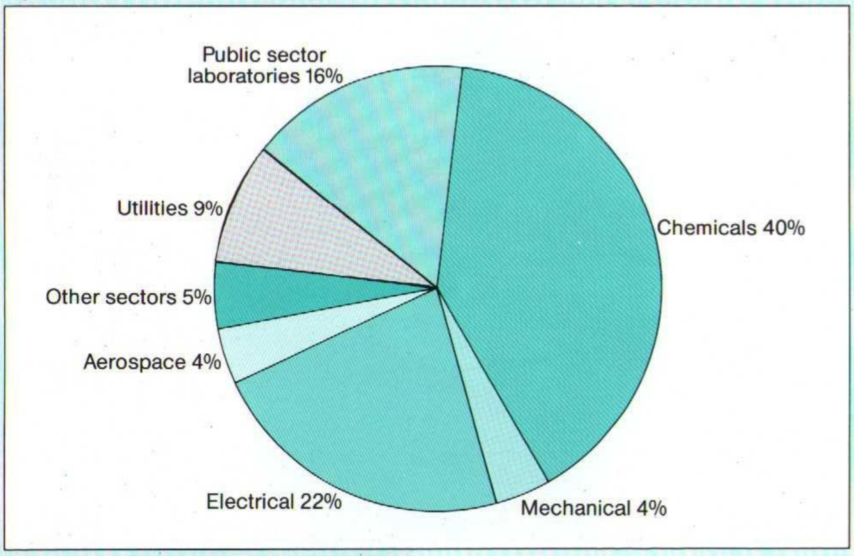
Committee subject area	Student take-up	% of total take-up
Astronomy and Planetary Science Board	3	0.3
Engineering Board		
ACME	*12*	*1.4*
Environment	*17*	*1.9*
Joint ESRC-SERC	*6*	*0.7*
Machines and Power	*52*	*5.8*
Marine Technology	*9*	*1.0*
Materials	*97*	*10.9*
Process Engineering	*53*	*5.9*
Total	246	27.6
Nuclear Physics Board	5	0.6
Science Board		
Biological Sciences	*174*	*19.6*
Chemistry	*192*	*21.6*
Mathematics	*16*	*1.8*
Physics	*50*	*5.6*
Science-based Archaeology	*2*	*0.2*
Total	434	48.7
Biotechnology Directorate	32	3.6
IT Directorate	171	19.2
Grand total	**891**	**100**

The Cooperative Awards in Science and Engineering (CASE) scheme allows postgraduate students to work on projects with an industrial flavour, that are formulated jointly by a firm and a department in a university, polytechnic or college. This approach to the doctoral research programme was pioneered by SERC in 1967, and the present annual intake to the scheme is about a third of the total number of SERC research studentships awarded each year.

The following brief accounts of three recently completed CASE projects are a random selection that give some idea of the type of experience that the scheme allows the student access to.

Compiled from information provided by Dr P Powell (RHBNC), Dr J Vincent (Reading University) and Dr A Weston (Manchester University).

Distribution of CASE partners by industrial sector



Some 1330 CASE studentships were current at the end of 1986. Of these, 240 involved public-sector research laboratories; the rest, organisations in the manufacturing and service industries.

Novel brake fluids

This CASE proposal was drawn up following a visit to the Department of Chemistry at Royal Holloway and Bedford New College by Dr Jane van Tilborg, a former student there. At that time Castrol, her employers, were formulating and testing some novel brake fluids. With hygroscopic brake fluids, water gradually accumulates, causing deterioration in performance and ultimately even failure of the braking system, especially in demanding applications such as motor racing. In Castrol's Special Racing Fluid (SRF) the water is removed by reaction with suitable silicon esters. Castrol wanted to understand the exact nature of the components in the commercial material and also in its hydrolysis products.

The student to fill the CASE studentship, Simeon Bones, was selected by interview at Castrol, and spent a month at the beginning of the project at the Castrol Research Laboratory at Pangbourne. In this way he learnt how to prepare the silicon esters and became familiar with some analytical techniques, especially size exclusion chromatography, for which facilities were not available in the College. This technique proved very valuable in separating the components of SRF; the molecular weights of the components were estimated from their relative retention volumes by using a calibration plot constructed from data on silicon esters prepared and characterised by the Department. Then followed an elucidation of the kinetics of hydrolysis using a variety of techniques including nuclear magnetic resonance and ultraviolet spectroscopy.

During the final year Castrol suggested studies on a related system, which in trials was proving even more effective than SRF. These results complemented the student's earlier work because of the different chemical nature of the second material. This new brake fluid is likely to be introduced commercially in the near future. After completion of the practical work for his PhD, Simeon Bones was commissioned by Castrol to measure the rates of hydrolysis of the commercial material at different pH values. This information was required by the Health and Safety Executive and the Department of the Environment, to enable the material to be included in the EEC register of new materials.

The project provided good research training covering a wide range of techniques at the 'applied' end of the spectrum of academic research work, which nicely matched the intentions of the student to pursue a career in the chemical industry.

A new field in pharmacological research

In 1982 a CASE project was set up by the Department of Physiological Sciences in Manchester University and Beecham Research Laboratories, Harlow. Included in the research programme was the investigation of the mode of action of a novel series of compounds with blood-pressure-lowering properties. The study showed that the lead compound BRL34915 belonged to a new class of drug, capable of opening potassium ion (K^+) channels in mammalian smooth muscle. This exciting discovery has given researchers a new tool for the study of ion channel opening mechanisms and initiated research by pharmaceutical companies in the race to capture a share in the £4 billion a year market for antihypertensive drugs.

Preliminary experiments in 1981 by Beecham had revealed an unknown mechanism of action in a novel series of synthetic compounds. The CASE proposal to SERC was successful and Sheila Weir, a graduate in biochemistry/pharmacology from Strathclyde, was selected to fill the award.

The first year of the project was taken up in perfecting a methodology for the assessment of vascular smooth muscle activity. In January 1984 the long-awaited samples of BRL34915 arrived in Manchester, and in a short time it became clear that the substance had some unique properties. Its inhibitory profile in isolated blood vessels was unlike that of any other compound known to the Manchester workers. Microelectrode recordings from vascular smooth muscle were made and the drug was found to produce cessation of on-going electrical activity together with a hyperpolarisation which raised the membrane potential to the region of the theoretical potassium equilibrium potential. Ion flux experiments followed and it was concluded that a new class of synthetic inhibitory agent had emerged.

Sheila Weir's work then continued using Beecham's *in vivo* facilities at Harlow. The existance of a firm working hypothesis allowed previously anomalous results to be explained and the K^+-channel opening action of BRL34915 was confirmed using additional techniques in both Harlow and Manchester.

In spite of the excitement, there were doubts, frustrations and disappointments. Was the proposed mechanism of action really correct? If so, would it be useful in man? What were the likely side-effects? Would there be enough money to bring the work to a satisfactory conclusion?

Although problems were encountered, the project was of great benefit to all participants. Sheila Weir obtained her PhD (on time) in late 1985. She then obtained a post-doctoral fellowship with Ciba-Geigy. Four papers have so far resulted directly from her work, and collaboration between Beecham and Manchester has thrived. A grant of £45,000 from Beecham has enabled the appointment of a research associate in Manchester for further studies in the field. Five additional CASE students, in collaboration with Beecham, Ciba-Geigy, May & Baker and Roche, have continued the work and extended it to other substances.

BRL34915 is currently under intensive clinical evaluation in man, initially for use in the treatment of high blood pressure. Up to 15% of the population in developed countries suffer from this condition, which in most cases is of unknown origin. Another possible use of the discovery is in the treatment of asthma and peripheral vascular problems like Raynaud's Disease, conditions which affect millions around the world.

Mother-of-pearl

Mother-of-pearl (nacre) is a material composed of thin plates of chalk (in the form of aragonite) stuck together with a protein glue; it is found in many types of snail and shell-fish. The interest of this material is that it is 95% chalk and yet very strong.

Glass fibre/resin materials, which have somewhat similar properties, contain equal amounts of glass fibre (which is cheap) and resin (which is oil-based and expensive). An artificial nacre would use a tenth the amount of resin and so be much cheaper, with little loss in useful properties such as strength and durability.

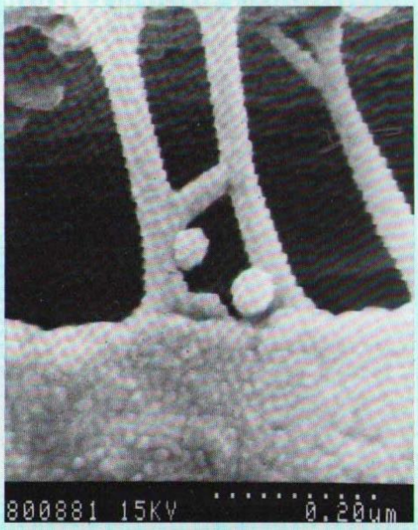
At the suggestion of ICI, the Biomechanics Group of Reading University set up a CASE project to examine the material. An Oxford zoology graduate, Andrew Jackson, was accepted for the studentship; his first task was to learn some engineering and materials science, especially fracture mechanics, so he attended a selection of lectures in the Engineering Department.

The first experimental part of the project involved comparative mechanical testing against commercially available ceramic composites containing hard particles in a resin matrix. This showed that nacre was not quite the 'wonder material' which previous workers had suggested it might be and that its properties were more or less predictable when the right theory was used with the right experiments.

The collaboration with ICI was indispensible to the next phase in the project, since they had far better electron microscopy equipment than the University, and some sophisticated hardware which could analyse the surface chemistry of a sample of material. The results from a long series of analyses following successive etchings showed that the glue in nacre is highly specialised, possibly designed to match the spacing of the atoms on the surface of the aragonite crystal. The glue itself is then kept slightly wet, allowing limited movement between the aragonite plates. This is part of the toughening mechanism and gives the nacre a degree of ductility, a property usually associated only with metals. Another mechanism is revealed when two plates of aragonite are pulled apart: as the nacre is broken, small strings of the protein glue are stretched across the gap. This process absorbs energy and so contributes further to the toughness of nacre.

The stratified surface chemistry and the engineering properties of nacre have now been firmly established. To produce a useful new material based on nacre would take much more research and at present there seems to be no drive in that direction, but the published results of this work exist as a basis for any such future developments.

As for Andrew Jackson, his experience during the CASE project changed his outlook from that of the 'pure' scientist and developed his interest in the industrial application of scientific ideas. He now works for a firm developing new ideas for wound dressing and splints.



Strands of protein stretching between two plates of nacre which have been pulled apart. Each strand is about 0.04 micrometres in diameter and 0.3 micrometres long. The stepped appearance is due to digital processing of the captured electrons reflected from the specimen.

Conduction loss diagnostics in polymers

Dipolar relaxation represents the major but not the only source of power loss in polymer dielectrics. Although these excellent insulators possess quite negligible bulk electronic conductivities, Joule (that is, conduction) losses may nevertheless limit the useful field and temperature ranges of a capacitor, especially when operating under DC bias or pulsed conditions. A group in the Department of Physics at Birkbeck College, London, has been carrying out studies of the Joule losses, supported by a grant from SERC's Materials Committee. The work is described here by Dr John Hirsch.

Three residual sources of Joule loss need to be considered. They are: bulk ionic conductivity, bulk electronic conduction due to electrons or holes injected by one or both metal electrodes, and surface leakage. The first, ionic conductivity, originates from impurities in the raw material or introduced during manufacture. The second, injection of electronic carriers, is promoted by high fields and temperatures. The injected carriers cannot freely cross the sample, but become deeply trapped in transit. Traps in polymers can store charge for long periods at room temperature, a feature which is exploited in the fabrication of electrets. The third source, the existence of surface leakage, is well documented but, as yet, not understood. It is not even known whether its character is electronic or ionic.

A group at Birkbeck College has recently completed comparative studies of the Joule losses in the polymers polyethylene terephthalate (PET) and polypropylene (PP). Both are commonly used in capacitors, PP for lowest loss. The studies involved three complementary experiments: measurement of the time-resolved absorption current; depolarisation by electron bombardment; and thermally stimulated depolarisation (TSD). All are well known methods, but their diagnostic strength lies in their combination.

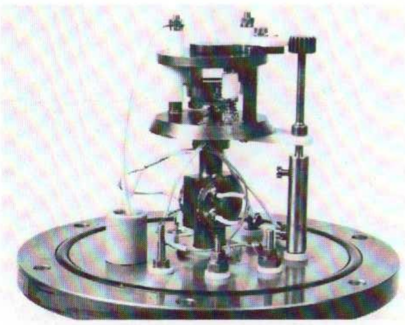


Figure 1: Sample holder for high-field absorption and depolarisation experiments.

Measurement of the time-resolved absorption current

The absorption current is the charging current through a capacitor, after subtracting the displacement current due to the geometric capacitance and electronic polarisation. When entirely caused by dipolar activity, it can be related to the dipolar loss/frequency spectrum by Fourier transformation. In this basic experiment, both the temperature and the field are varied to observe the development of conduction processes.

All residual polarisation is first removed by annealing just below the softening temperature of the polymer. A single voltage step, corresponding to fields up to 2 MV/cm, is then applied with a rise time of $\leqq 1$ μs. The current detector input is short-circuited for a few μs to by-pass the initial displacement surge (typically 0.5 A). Subsequently, the absorption current is sampled at binary intervals (10, 20, 40, 80 μs and so on) with a resolution of 1 pA. The resorption current (the discharge current resulting from starting the charged capacitor) is measured in a similar manner. After a few seconds, the current can be diverted into an electrometer to extend the record. In this way, a transient may be recorded over a time span from 10 μs to, say, 24 hours.

The contribution from surface leakage is measured by using sample capacitors with different electrode diameters. Injection effects are studied by using different metals for the electrodes. Dipolar loss leads to absorption and transients which are mirror images of each other, usually decaying as $t^{-n} (n \lesssim 1)$ over many decades of time (figure 2). Superimposed on this, the ionic component gives rise to a conduction tail which continues to decay, but more slowly. By contrast, contact-injection produces a tail which not only is sensitive to electrode metal, but tends to level out. Under contact-injection, the resorption transient also may become distorted by the internal field of the trapped space charge. All these features are recognisable in figure 2.

Depolarisation by electron bombardment

When a previously polarised sample is probed with a weak electron beam which induces temporary conductivity, the internal fields give rise to discharge transients. If the space charge is substantial, its strength and spatial distribution can be determined. If it is weak, it may still be possible to deduce at least its sign. Homocharge (for example, negative charge near the cathode) indicates the presence of injection; heterocharge (for example, positive charge near the cathode), ionic polarisation.

Thermally stimulated depolarisation

In the TSD experiment, a sample is first voltage-polarised (charged). Its temperature is then raised at a constant rate. Whenever a temperature is reached at which a dipolar relaxation is activated or a carrier trap emptied, a peak is produced in the depolarisation current 'thermogram' (figure 3). It is difficult to distinguish between peaks of dipolar and ionic origin, but peaks due to detrapping may be identified by varying the polarising conditions, and by filling the traps with carriers generated by electron beam (or X−) irradiation with the sample short-circuited, as seen in figure 3.

To illustrate the information which can be gathered by the combination of these experiments, we summarise the results obtained for PET and PP. In PET, strong injection was observed even at room temperature. This swamped any ionic or surface contributions, neither of which could be resolved. An aluminium cathode, which has a relatively low work-function, injects electrons. At 20°C, most of these become deeply trapped within about 1 μm of the surface, and can represent a charge as high as 0.25 CV (C = capacitance, V = voltage; at 1 MV/cm). A gold anode, which has a relatively high work-

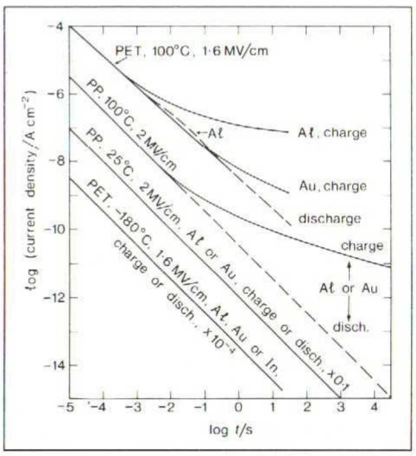


Figure 2: Representative absorption (charge) and resorption (discharge) current transients for PET and PP capacitor-type samples with different electrodes.

function, injects holes but only weakly and at higher temperatures. Thus, a capacitor with gold electrodes should possess lower power loss and work at higher temperatures and fields than one with conventional aluminium electrodes.

In PP, on the other hand, surface leakage is prominent and exhibits a complex field and time dependence (figure 4). Unless corrections are made to allow for the surface component, the behaviour of the bulk current cannot be validly analysed. There is no detectable electronic carrier injection from aluminium or gold electrodes. The conduction tail in figure 2 arises from residual ionic conductivity, as confirmed by the detection of heterocharge under electron-beam probing. The superior performance of PP compared with PET capacitors, therefore, is only in part due to the lower dielectric loss; the conduction loss to be expected in PET capacitors with alumimum electrodes is also absent.

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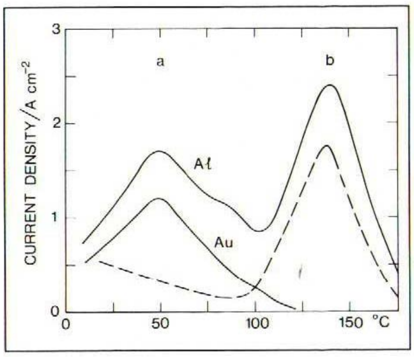

Figure 3: TSD thermograms for PET. a: dipolar relaxation, b: electron trap. Solid curves: voltage-polarised at 20°C. Electrons are injected by aluminium (Al) but not gold (Au) electrodes. Dashed curve: electron-implanted by bombardment in short-circuit, dipolar peak absent.

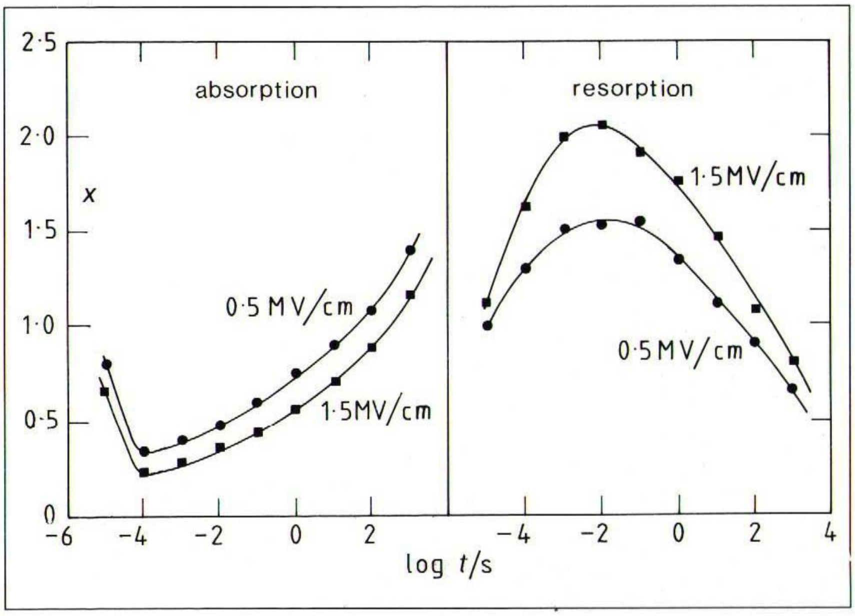

Figure 4: Evolution of surface/bulk current ratio X for PP with 14 mm diameter Al electrodes at 100°C.

Second coordinator for powder processing

A second SERC/Department of Trade and Industry Powder Processing Initiative Coordinator, Dr R J E Glenny, has been appointed, to support Dr I Jenkins, the current Coordinator. Dr Glenny will specialise in projects on ceramic materials.

During the early 1980s, the Department of Industry (now the Department of Trade and Industry, DTI) and SERC's Materials Committee recognised the growing importance of powder processing technology. In February 1982, Dr Jenkins was appointed as part-time SERC/DTI Coordinator to encourage the development of collaborative projects between industry and academics aimed at overcoming the technical and economic barriers to a more extensive exploitation of the technology in the UK.

The research and development programme has included powder metallurgy, engineering ceramics and solid-phase compacted polymers. Some 60 projects to a total value of £2.9 million have been funded by the Materials Committee since the launch of the programme in 1982. The continuing increase in the number of projects in the powder programmes, in particular a substantial growth in research projects on engineering ceramics, has led to the new appointment. Dr Glenny will be active across the whole programme, but will take a particular interest in research on ceramic materials.

Dr Glenny has been a consultant to UK industry and Government since 1983 when he retired from his position as Group Head of Materials, Structures and Aerodynamics Departments of the Royal Aircraft Establishment. He has maintained an interest in engineering ceramics and ceramic-matrix composites since his early personal researches on the creep and thermal fatigue behaviour of ceramics and cermets for gas turbine blading.

Dr Glenny can be contacted at:

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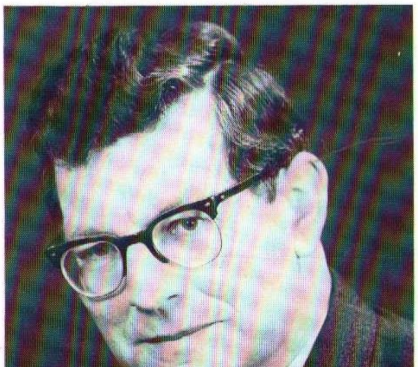
Further information on the powder processing programme can be obtained from the Secretary, Mr D R Mullins, at SERC, Central Office, Swindon (ext 2338); from Dr Jenkins, the Powder Processing Initiative Coordinator, at Drift Cottage, Worthing, Dereham, Norfolk NR20 5HE; telephone Dereham (0362) 81601; or from Dr Glenny.



Dr Ervine Glenny

Biochemical engineering centres

Genetic engineering and other new techniques in biotechnology have the potential to provide more potent medical drugs with fewer side effects, to make the diagnosis of disease simpler, cheaper and more reliable, to clean up polluted environments more effectively and to protect crops against disease without the need for chemical sprays, among many other uses. But in order for any of these applications to become reality on a large scale, beyond a few specialised areas, innovative molecular biology must be accompanied by equally innovative engineering. Improvements in the design of the reactors in which cell cultures are grown to produce enzymes and medical drugs, and in the technology used to separate and purify these products, can cut the costs of manufacturing the high-value products of biotechnology by a factor of ten or more.

That is why SERC's Biotechnology Directorate in a major strategic initiative has decided to establish Centres of Biochemical Engineering at Birmingham University and University College London. A £1.6 million award to Birmingham University will support a four-year programme in which engineers will scale up bioreactors to enable the latest culturing technology to be used on an industrial scale. A £1.9 million award to University College London will enable the team to develop better ways to support delicate living organisms in reactors, and to use computers to control the growth of cell cultures and the production of their products more effectively.

Those are just a few examples of the work planned for the new Biochemical Engineering Centres. Typical of the challenges faced by the new Centres is the need to persuade enzymes which naturally work in water to work instead in the organic solvents favoured by industry. If biologists and engineers working together can crack this problem then it will open the way to a massive expansion of the use of biotechnology in the chemical industry.

The decision to establish Centres in Biochemical Engineering was taken in principle early in 1986. Discussions with industry indicated general support for the development and in May 1986 the Directorate invited bids from all universities to establish Centres. More than 20 universities submitted bids and a short-list of six universities was drawn up. All six were visited in July 1986 before a final decision was taken to encourage proposals from Birmingham and University College London.

The aim of the Directorate in setting up Centres of Biochemical Engineering is to ensure that the UK maintains its position as one of the leading nations active in research and training in the subject. Support for Birmingham and UCL will enable these institutions, which already have significant activities in biochemical engineering, to maintain and develop further their position in the face of increasing international competition. At this stage the Directorate has only sufficient funds to allow two Centres to be supported. Should additional money be forthcoming, then the Directorate would want to encourage the formation of additional Centres, acknowledging that many of the proposals put to it had worthwhile funding opportunities.

The Centres will undertake a range of research and training activities. At the research level their programmes will be complementary and cover many different facets of biochemical engineering. In addition, the Centres will extend their contract research activities with industry, which will build upon their research base funded by the Directorate.

The Centres already offer a range of training activities such as one-year Masters courses, three-year training in research to PhD level and short courses. The Directorate wishes to see these activities continued and expanded, especially to meet identified training needs by industry.

To steer and monitor the work of the Centres, the Directorate will establish a Steering Group common to both Centres.

For further information, contact:

Mr A N Emery, Department of Chemical Engineering, Birmingham University; telephone 021-472 1301;

Professor P Dunnill, Department of Chemical and Biochemical Engineering, University College London; telephone 01-380 7368;

Dr J Godber, Biotechnology Directorate, SERC Central Office, Swindon (ext 2279).

Separation process manager appointed

Professor Jack Richardson FEng has been appointed programme manager for the new Biotechnology Directorate/ Process Engineering Committee joint Separation Processes Initiative.

Besides the day-to-day management of the programme, his task is to coordinate academic research activity and to encourage interaction between research groups and UK companies towards innovative and improved separation processing techniques.

Professor Richardson, who retired last year as Head of the Chemical Engineering Department at the University College of Swansea, can draw on more than forty years' experience in his subject, and is co-author, with John Coulson, of *Chemical Engineering*. Apart from his close association with the Institution of Chemical Engineers, he has served on various committees and working parties of the SERC. Former Chairman of the Research Group of the Government's Advisory Committee on Major Hazards, Professor Richardson is now a member of the Advisory Committee on the Safety of Nuclear Installations.

He will continue to be based at Swansea, where he may be contacted at the Department of Chemical Engineering; telephone Swansea (0792) 295194.

Professor Jack Richardson

Communications in Unison

Unison is a £2 million, four-year, Alvey collaborative research project investigating the possibilities for satisfying the communications requirements of the modern office with a single integrated communications network. The collaborators in the project are Acorn Computers Ltd, the Cambridge University Computer Laboratory, Logica Ltd, Loughborough University of Technology and the Rutherford Appleton Laboratory (RAL). The project is described here by John Burren of RAL.

The type of equipment expected to be found in the 'modern' office includes:

- a telephone, or similar equipment for voice communication
- a personal workstation with high-resolution screen, to access information and to prepare documents
- a laser printer
- a document scanner for facsimile capture and communication
- video equipment: colour television cameras and monitors for the capture and display of both still and moving video images.

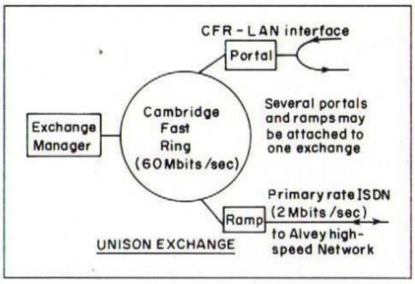
For communications and processing to be integrated, all information including voice and video must be treated in a digital fashion. Voice and video signals are converted to digital form by sampling and digitising the signal amplitude at regular intervals. A standard method of sampling voice produces a constant 64 K bits/sec and, depending on the frame-rate and the degree of compression, video requires bandwidth in the range of hundreds of kilobits to many megabits per second.

Two networking technologies, integrated services digital network (ISDN) and local area network (LAN), are being used in the Unison project. ISDN is the technology that the telephone companies of the world are intending to use to change from analogue to digital telephony and provide simultaneous data access. As far as customers in Europe are concerned ISDN provides two services: a basic rate service at 144 Kbit/s and a primary rate service at 2.048 Mbit/s. The former is the equivalent of the normal telephone line and is configured as two 64 Kbit/s channels and a 16 Kbit/s signalling channel, allowing, say, a telephone call and terminal access to a computer to be carried on at the same time. The primary rate service is intended for the connection of private branch exchanges and gives thirty 64 Kbit/s channels and a signalling channel, with the remaining bits used for framing. In advance of the introduction of ISDN in Britain towards the end of the decade, the Alvey Directorate commissioned British Telecom to build a small pilot ISDN with one exchange in London. The Unison collaborators all have primary-rate links to this exchange.

Locally, the communications requirements of the office equipment will be provided by LANs of the Ethernet, Cambridge ring or Cambridge fast ring type. Rather than terminating the primary-rate ISDN links with a branch telephone exchange, a fast-packet switched exchange has been developed. This exchange ring has attached a number of 'ramps' and 'portals' and a processor acting as the exchange manager. A ramp interfaces the exchange to a primary rate ISDN link and a portal interfaces a LAN to the exchange (see figure). A problem with currently proposed implementations of ISDN is that there is no simple method of combining the 64 Kbits/sec channels into higher rate channels. These are essential for the packet style of communication envisaged for the integrated office and the ramp implements a complex scheme for amalgamating basic voice channels to produce higher speed channels. Within the limitation of the 30 channels of 64 Kbit/s, the ramp can configure any arrangement of amalgamated channels to different destinations that have bandwidths that are multiples of 64 Kbit/s. This complex processing task has been accomplished by the use of an array of five Inmos transputers.

A model high-technology office together with a Unison exchange connected to the ISDN was demonstrated at the Alvey conference at UMIST in July. Further investigation of the Unison network for the office application is planned and for post-Alvey the technology should be applicable in the areas of 'intelligent' buildings, medical communications and technology-assisted training.

J W Burren
Rutherford Appleton Laboratory



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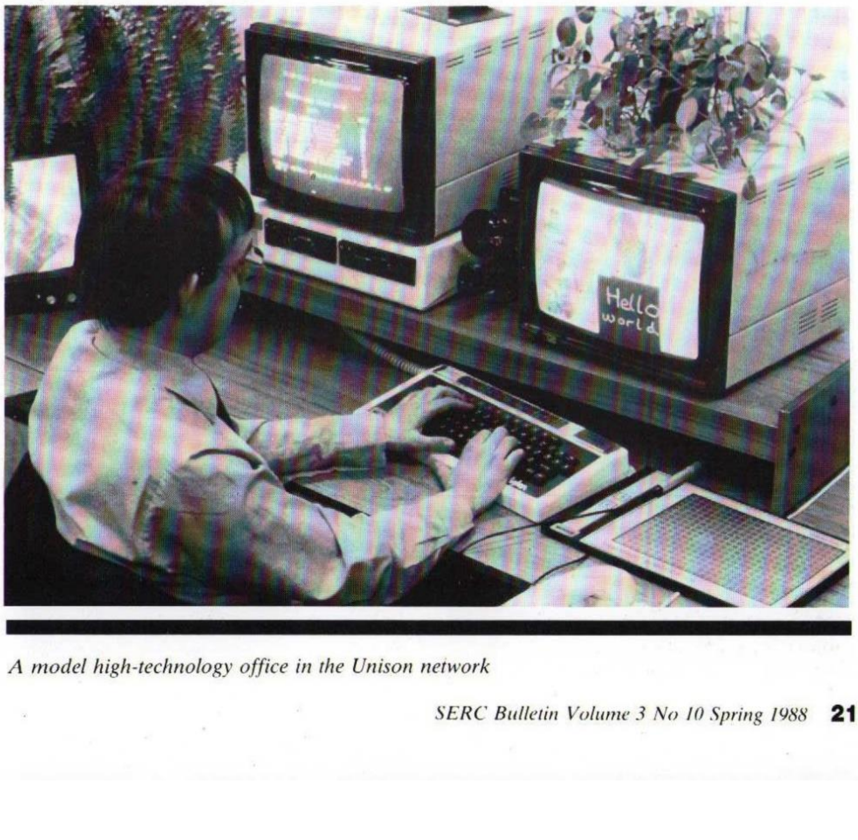


A model high-technology office in the Unison network

Software Tools Centre at Kent

Graphics workstations provide an opportunity for a new generation of highly interactive software products that are far easier to use than their predecessors. This article, by Professor Peter Brown of Kent University, describes the work of his SERC-funded Software Tools Centre in producing such software.

Graphics workstations provide a base for constructing software that is much easier to use. For example, the user of good workstation software can manipulate objects on the screen by pointing at them, and perhaps 'dragging' them around. No command language is needed and, when the user points at an object, he or she gets feedback on the nature of the object and what operations can be performed on it. Information can be managed effectively using pop-up displays and can be enhanced by graphical representations of the current context and the current state of progress. In short, a graphics workstation provides a much higher bandwidth of communication between human and machine, and as a result is leading to a new generation of highly interactive software products. The advantages of this approach apply even when the objects being manipulated are textual rather than graphical.

Nevertheless the graphics workstation is not a magic recipe for good software: there are plenty of software developers who, when given extra freedom, duly hang themselves. The more dimensions there are to the human interface, the harder it is to get it right.

SERC workstation policy

In the early eighties, SERC saw the potential of graphics workstations and introduced its 'common base policy', which planned that the basic computing equipment for all researchers should be a graphics workstation. This policy suffered from considerable problems with the early hardware and software, but the main fault with the policy itself was, we believe, simply that it was ahead of its time. Recently it has been made more flexible, and has evolved into EASE (Engineering Applications Support Environment). Hardware and software are now vastly improved, and the advantages of the original policy are now being exploited.

The Software Tools Centre

Following on from this policy, Kent University was commissioned in 1983 to act as a Software Tools Centre for graphics workstations. The aims of the Centre are:

- to meet the needs of the SERC community, by developing tools of use to the majority, rather than special-purpose tools for one discipline.
- to improve user productivity, by designing novel ways of exploiting workstations.
- to deliver tools to the Rutherford Appleton Laboratory for distribution: once a need had been established and a tool specified, deadlines are set for the delivery of each finished product.

The original contract ended in 1986 and, we believe, its aims were fully met. A range of tools has been developed and are being used increasingly widely, particularly on the SUN-3 workstation. Every deadline was met, and user reaction was sufficiently favourable to convince SERC to renew the work for a further three years.

The most popular tools are:

vdiff	for comparing two files and showing the differences;
fs	which allows graphical viewing and highly interactive manipulation of the file store;
guide	a 'hypertext' tool for displaying documents on computer screens;
ups	a graphical debugger; and
med	a system to help software developers construct menus.

All of these tools run under Unix and have been written in a way that allows them to be ported to any Unix workstation. Perhaps the greatest lesson learned from their development is that successful highly interactive tools are not simply previous tools dressed up, but involve a complete rethink on how users should communicate with a computer. As a result, the work has produced several novel approaches on presenting information to the user in a clear and easily manipulated way.

```
3d2
< This has been added
6a6
> This line is extra
10,11c10
< This line is not exactly
< the same
---
> This line is not the same
16c15
< This has changed slightly
---
> This has changed very slightly
```

Figure 1: Output from the standard Unix file comparator.

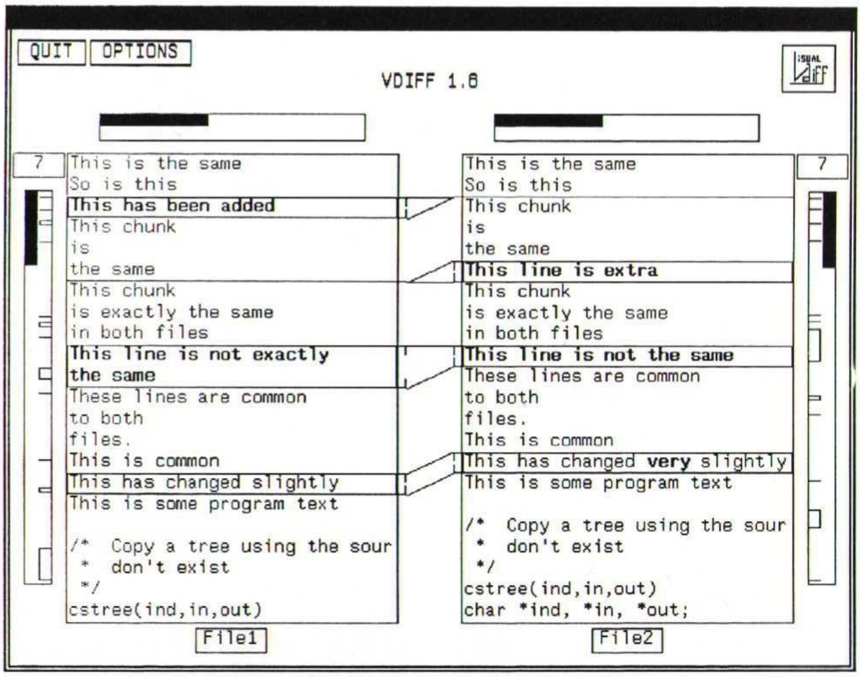


Figure 2: Output from the new file comparator.

The comparator program

The general flavour of the tools is well illustrated by the file comparator tool, *vdiff*.

Unix itself supplies a file comparator tool called *diff*, which is neither graphical nor interactive. Figure 1 shows a sample of its output, which can hardly be claimed to be friendly. The aim of *vdiff* is to put a friendly face on to *diff* by presenting its output in a comprehensible and interactive way. Figure 2 shows *vdiff* in use. The two files to be compared (which can be any text files — programs, documents, etc) are displayed side by side. Lines are drawn between the two files to show where the differences lie. Material that is in one file but not the other is shown in bold type.

The real gain of *vdiff* is not, however, its presentation but its degree of interaction. The user can point at either file with the mouse and, by holding the mouse-button down can scroll continuously through the file. *Vdiff* automatically keeps the two files lined up; for example if the second file has an extra hundred lines inserted, then scrolling of the first file will temporarily stop while the hundred lines are passed over, and will then resume when the files are in phase again. The scroll-bars (the tall rectangular areas on each side of figure 2) show where the files are currently focused: the black part represents the part you can see, in the context of the whole file. The nicks on the inside of each scroll-bar show where the differences lie. A scroll-bar can be used to jump immediately to any of these differences. We believe that the *vdiff* approach is a dramatic improvement on *diff*: the user gets an immediate appreciation of the difference between files, and sees each difference in context.

Recently the staff of the Houses of Parliament have become interested in this work, since they need to monitor the changes to Bills as they pass through Parliament.

Related FORTRAN work

SERC also financed at Kent University a complementary programme to the Software Tools Centre. This was the Fortran Libraries Centre, under the direction of Dr T R Hopkins, which shared the same aims as the Tools Centre but was oriented specifically to the Fortran community. This work has been equally successful, and support has been renewed in a new contract combined with the Tools Centre.

Staff

The Tools Centre has been fortunate in the quality of research staff and lecturers associated with the project: David Barnes, John Bovey, Mark Russell, Peter Siemon and Mark Wheadon. All have achieved the difficult balancing act between, on the one hand, working all hours concentrating on the minutiae of implementation and, on the other, thinking in terms of the user's view of the tool rather than the tool as an end in itself.

The future

Graphics workstations are becoming increasingly cheap and thus increasingly widespread. In the future a large part of the software market may be for highly interactive workstation software. We hope British industry obtains a good share of this market, and particularly that SERC's early move into graphics workstations will provide the basic expertise for this.

Professor Peter Brown
Computing Laboratory
University of Kent at Canterbury

Computational science: £1 million initiative

SERC has set up an initiative in computational science to provide facilities for local (distributed) high-performance computing in academic centres, as recommended by the Forty Report on advanced research computing.

The initiative was conceived by the Science Board to meet the local computing needs of its communities in the biological sciences, chemistry, mathematics and physics. It proposed a five-year programme which aims at providing about £21 million for the purchase of host and attached processors at 24 sites, with some 125 workstations and including personnel support.

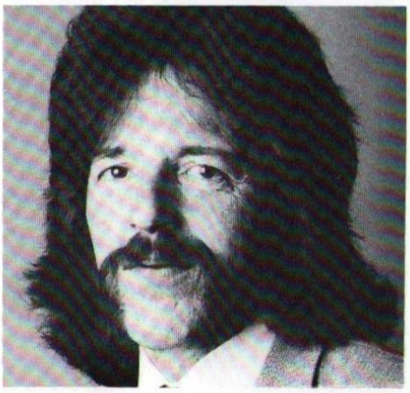
The Science Board has initially been able to provide only £1 million of pump-priming funding for the 1986-87 academic session. The demand for this funding has been considerable, with more than 50 requests totalling more than £9 million having being received. In this highly competitive situation, the Board was able to make only a limited number of awards. The figures in the table include contributions from the Science Board's subject committees.

The Science Board has agreed to provide a further £1 million for this initiative in the 1987-88 academic session.

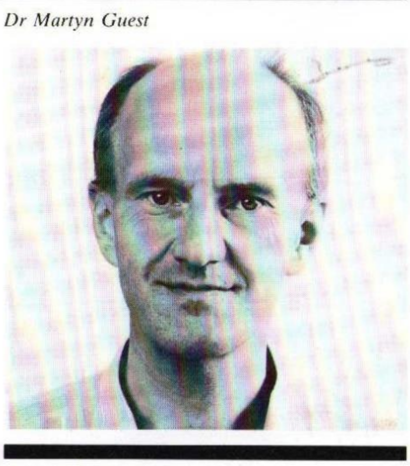
Investigator	University	Amount £
Dr M P Allen	Bristol	150,000
Professor B H Bransden	Durham	100,000
Professor D B A Epstein	Warwick	143,000
Dr A J Geddes	Leeds	63,000
Professor I H Hillier	Manchester	133,000
Professor J C Inkson	Exeter	135,000
Professor E W Laing	Glasgow	39,000
Dr P M Lee	Lancaster	16,000
Dr P A Maksym	Leicester	52,000
Professor J B Pendry	ICST	160,000
Dr L K Tyler	Cambridge	48,000
Professor D W Wallace	Edinburgh	350,000*

*Cofunded by Meiko Ltd and the Nuclear Physics Board

Two coordinators have been appointed to support the initiative: **Dr John Inglesfield** and **Dr Martyn Guest**, both of whom work in the Theory and Computational Science Division at Daresbury Laboratory and, through the Collaborative Computational Projects, have developed wide-ranging links with the academic community.



Dr Martyn Guest



Dr John Inglesfield

Molecular chaperones

One of the basic principles of molecular biology is that all the information required to specify the structure and function of a polypeptide resides in the primary structure (the amino acid sequence) of that polypeptide. There are many excellent examples of this principle of self-assembly, but there are also some exceptions. Cases are now known from viral, bacterial, animal and plant sources where the correct folding of certain polypeptide chains and their assembly into oligomeric structures require the presence of other proteins that are not components of the final structure. Professor John Ellis FRS of Warwick University proposes that this latter class of proteins be termed 'molecular chaperones' and in this article he summarises the reasoning behind this proposal, and discusses work from his laboratory on a protein that is implicated in the assembly of the photosynthetic CO_2-fixing enzyme, ribulose bisphosphate carboxylase-oxygenase (rubisco), from its subunits inside chloroplasts.

The term 'molecular chaperone' was first used by Ron Laskey, now at Cambridge University, in 1978 to describe the function of nucleoplasmin, a soluble acidic nuclear protein that is required for the correct assembly of nucleosomes from separated DNA and histones in extracts of *Xenopus* eggs. If DNA and histones are mixed at physiological ionic strength, an instant precipitate results, but if nucleoplasmin is also present, nucleosome cores form. Laskey proposed that nucleoplasmin both promotes histone-histone interactions by reducing electrostatic repulsion between them and minimises the formation of non-specific aggregates by competing with the electrostatic attraction between histones and DNA. Nucleoplasmin is required only for assembly and does not itself form part of the nucleosome, nor does it carry any steric information specific for nucleosome assembly: this is known to reside in the histones. The term 'molecular chaperone' is appropriate to describe the function of nucleoplasmin because the traditional role of the chaperone in human affairs, if described in scientific terms, is to prevent the improper interaction of potentially complementary surfaces.

The proposal that the term 'molecular chaperone' be extended to other proteins stems from the realisation that a whole class of cellular proteins exists whose function appears to be to prevent the formation of 'improper' structures. The basic argument is that in some cases the transient exposure of charged or hydrophobic surfaces, normally involved in domain interactions within or between polypeptide chains, can result in 'improper' interactions to form incorrect structures. Molecular chaperones function to prevent the formation of such incorrect structures.

If this idea is correct, such molecular chaperones would be expected to occur in all cells which synthesise oligomeric proteins whose subunits have the potential to interact incorrectly. Hugh Pelham, of the Medical Research Council's Laboratory of Molecular Biology at Cambridge, has marshalled the evidence for such chaperones in animal cells and has also suggested that these proteins may function to disassemble aggregated structures that are either no longer required (for example clathrin cages), or which form during stresses such as heat shock. This proposal is consistent with my definition of molecular chaperones since it is also part of the role of the human chaperone to disrupt improper liaisons that have taken place. Figure 1 lists examples of proteins that could be regarded as molecular chaperones.

Name	*Proposed function*
Nucleoplasmin	**Nucleosome assembly**
Assembly proteins	**Formation of the head of phage lambda and T4.**
Heavy chain binding protein	**Assembly of immunoglobulin**
Heat shock protein hsp 70	**Disassembly of nuclear aggregates**
Rubisco subunit binding protein	**Assembly of rubisco**

Figure 1: Suggested molecular chaperones.

Rubisco is a major target for genetic engineering because of its pivotal role in determining the relative rates of photosynthesis and photorespiration. Molecular biologists would love to be able to alter the properties of this enzyme to see whether the rate of net photosynthesis by crop plants can be increased, with consequent improvements in economic yield. Among the many technical problems to be solved before this question can be answered is the devising of a system in which mutated genes for rubisco can be expressed to produce an altered active enzyme. The synthesis of rubisco by higher plants is a complex process, requiring the interaction of two genetic systems. The genetic system located in the chloroplast produces the large subunit of rubisco, while the genetic system in the nucleus produces the small subunit of rubisco in precursor form in the cytoplasm. Assembly of the two types of subunit into the active holoenzyme occurs inside the chloroplast after import of the small subunit precursor from the cytoplasm (figure 2).

Sequences of cDNA encoding both the large and small rubisco subunits have been prepared from a number of higher plant species. When these sequences are introduced into the bacterium *Escherichia coli* in a form suitable for their expression, the bacterial cells synthesise both types of rubisco subunit. However these subunits do not associate with one another to form the holoenzyme and no enzymic activity is detectable. This failure of assembly is currently blocking all attempts to pursue directed mutagenesis studies on rubisco from higher plants; it is only with rubisco from certain prokaryotic organisms that success has been achieved.

SERC-supported research in the author's laboratory led to the proposal that another chloroplast protein — a molecular chaperone — is required for the assembly of rubisco from its subunits in higher plants. This proposal was based on the discovery that large and small rubisco subunits, newly-synthesised by *in vitro* systems, are bound non-covalently to another chloroplast protein before assembly into the holoenzyme.

This binding protein is itself oligomeric, consisting of two types of subunit that are nuclear-encoded and imported across the chloroplast envelope after synthesis in the cytoplasm in precursor form (figure 2). The emphasis of current research is on the characterisation of cloned cDNA sequences for the binding protein subunits from wheat so that they can be expressed in the same *E coli* cells as the wheat rubisco subunits to see whether they will permit rubisco assembly. We regard this approach as a good test of our proposal that the binding protein is a molecular chaperone, while success in this type of experiment would remove the block that prevents attempts to produce mutated forms of higher plant rubisco.

A recent discovery has encouraged the belief that these ideas have some merit. A search of a sequence database revealed high homology (50%) at the amino acid level between the sequence for one of the binding protein subunits from castor bean and wheat and a protein found in *E coli* and mycobacteria (figure 3). This *E coli* protein has just been identified by Roger Hendrix (University of Pittsburgh) as the product of the *groE* gene; this is a well known bacterial gene since it is required for the assembly of the head of phage lambda in infected cells. The *groE* protein binds non-covalently to one of the phage head proteins, and ensures that it interacts correctly with other phage head proteins, but it is not itself part of the mature head — in other words, it is a molecular chaperone. These observations suggest that the rubisco binding protein may have evolved from a general class of proteins required for assembly processes in a wide range of cells. At a recent Cold Spring Harbor meeting on heat-shock proteins, Richard L Hallberg (Iowa State University) reported the occurrence of a *groE*-like protein in mitochondria from yeast, maize and man. The proposed role for this mitochondrial protein is to mediate the correct folding of imported proteins after they have traversed the mitochondrial envelope in an unfolded state.

The idea that molecular chaperones are involved transiently in the assembly of certain oligomeric proteins clearly has implications for those biotechnologists who are encountering problems in the production of foreign proteins in bacterial cells in the required active form. It may be necessary to re-examine the normal synthesis of these proteins by techniques that permit the detection of non-covalently bound complexes to determine whether molecular chaperones are involved.

Professor R J Ellis FRS
Department of Biological Sciences
Warwick University

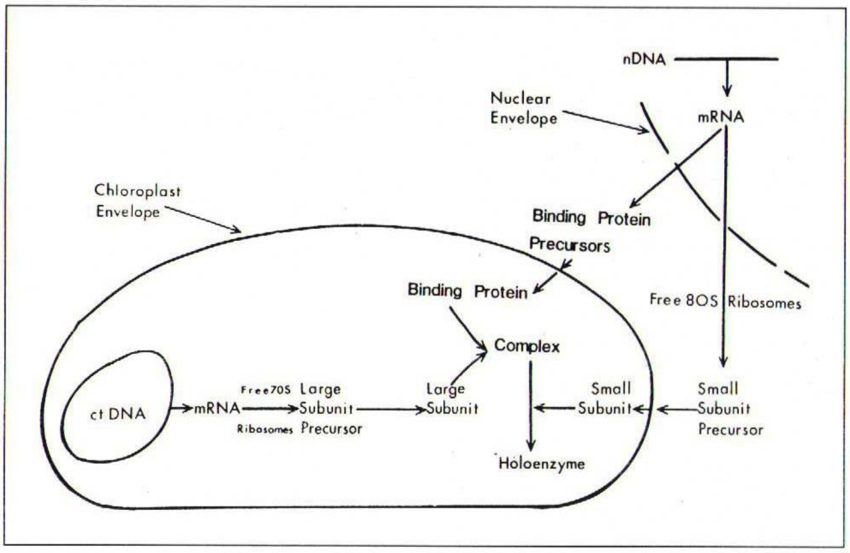


Figure 2: Model for the synthesis of rubisco in higher plants. Symbols: ct DNA, chloroplast DNA; nDNA, nuclear DNA.

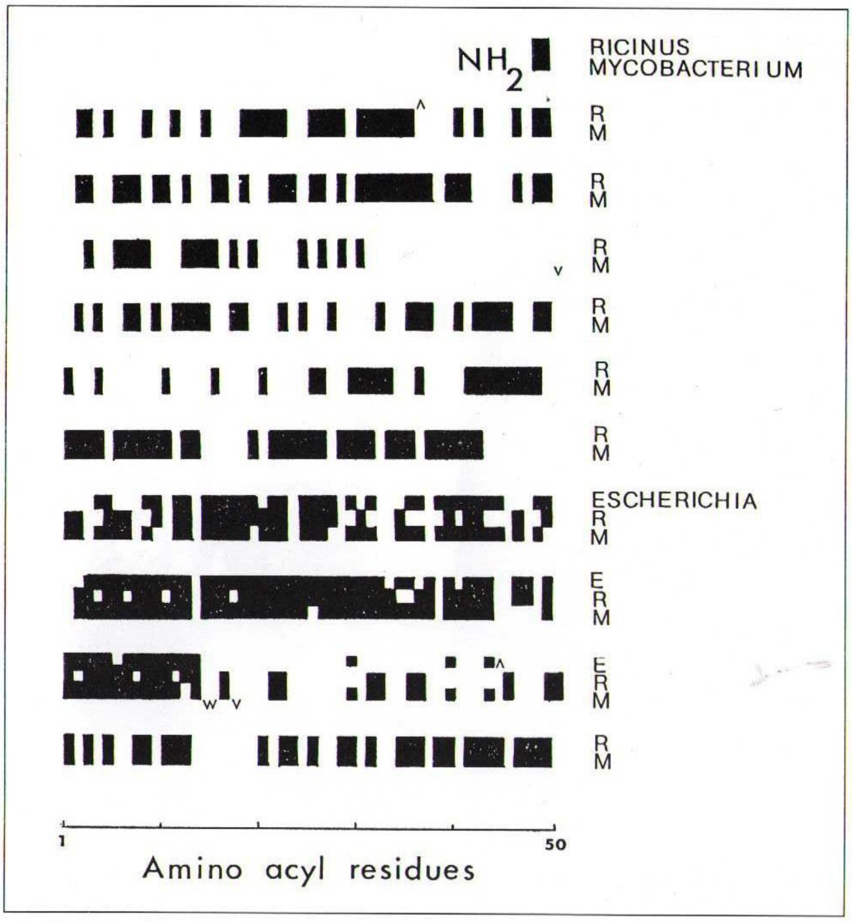


*Figure 3: Amino acid homology of the rubisco binding protein alpha subunit from castor bean (*Ricinus communis*) with the 65 kDa antigen from* Mycobacterium *and the* groE *protein from* Escherichia coli. *The sequences are aligned at the aminotermini (NH_2) and the blocks represent homology. Arrows indicate insertions or deletions made to preserve homology. Only part of the* groE *sequence is shown; the remainder also shows high homology to the binding protein sequence.*

Thermoluminescence

Applications to archaeological dating and environmental dosimetry

Thermoluminescence (TL) is a phenomenon well known to physicists; there is documentary evidence of early observations of TL by Robert Boyle in a paper given to the Royal Society more than 300 years ago. The suggestion that TL could be used as the basis of a technique for archaeological and geological dating was made comparatively recently, in 1953, by researchers at Wisconsin University. From the early development of the method, the great potential of TL dating in archaeology and geology was realised. The method has undergone considerable change since then, and in this article Ian Bailiff of Durham University reports on the latest developments.

The thermoluminescence dating method employs three key elements:

• the ability of TL minerals to register accrued radiation dose,
• the occurrence of a *zeroing event* where previously accrued latent TL is erased, and
• the presence of naturally occurring radionuclides (eg the uranium and thorium series and K-40) with half-lives long compared with archaeological timescales.

The Earth contains an abundance of TL minerals which have been registering environmental radiation dose since their formation millions of years ago. Some of these minerals, contained within artefacts or having formed deposits, are of chronological significance to archaeologists and geologists.

The intervention of Man by the use of fire provides a suitable zeroing event which removes previously accrued TL. Thereafter, the build-up of latent TL resumes in a natural radiation field provided by radionuclides, in the case of pottery, within the fabric and also within the burial medium after it has been discarded.

Natural events can also provide a zeroing event. Besides heating by volcanic material or fires, the action of sunlight (due to photo-ejection of trapped charge carriers) can act as a resetting mechanism for TL minerals that are not within an opaque medium such as fired clay. The technique has been applied to aeolian and water-lain sediments, mostly in periods of geological interest. We have recently started to investigate the application of sediment-dating to archaeological sites. This has arisen through collaborative work with researchers who have used sediments from inter-tidal zones to study sea-level changes during the Holocene period.

Thus TL dating requires:

1. recording the *natural* TL emission (that accrued since the zeroing event) and determination of its equivalence in radiation-dose units by comparison with the TL response to known radiation doses, and
2. evaluation of the natural radiation dose-rate.

Determination of these two quantities enables the evaluation of the deceptively simple TL Age Equation:

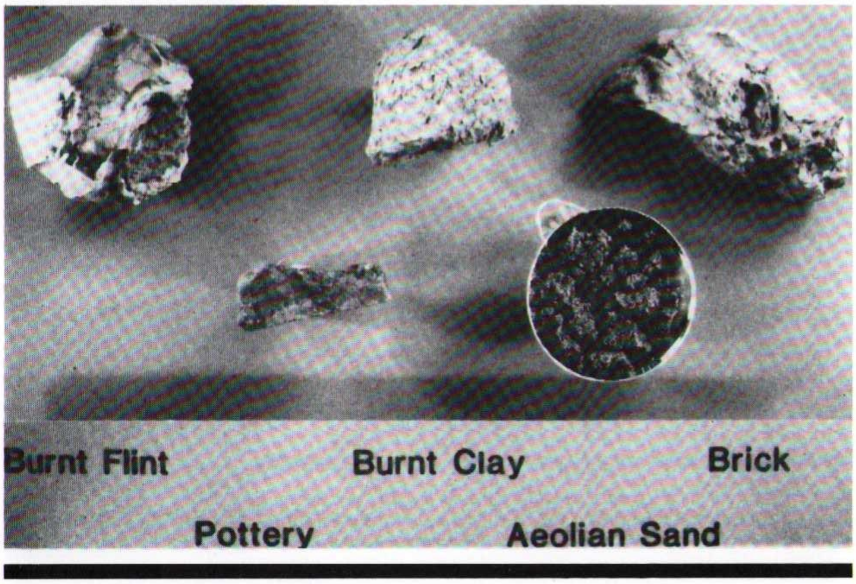
$$\text{TL age} = \frac{\text{dose accrued since zeroing}}{\text{radiation dose-rate}}$$

Although a number of different TL dating techniques have evolved, this equation describes the underlying basis of date calculation.

The inherent complexities of natural materials call for detailed experimental examination of the TL properties of dating samples. Factors ranging from defect type and relative concentrations, through thermal history to laboratory measurement conditions all play a role in contributing to the different TL properties observed from sample to sample. For this reason the development of instrumentation to enable semi-automated function has been of considerable interest to laboratories engaged in routine dating measurements. The apparatus requires a high degree of flexibility of control for combining research and routine use, and these features have been incorporated in our own recently developed instrument.

As experience in the use of the semi-automated system increases, we foresee the need for an expert system to attain full stand-alone 'routine' capability.

The TL measurements constitute one part of the dating procedure; determination of radiation dose-rate to TL crystals arising from radioisotopes within the TL sample and within the surrounding burial medium demand equal scrutiny. A variety of techniques is used, including TL dosimetry, alpha-, beta- and gamma-spectrometry, and chemical analyses to determine the total dose-rate and its contributors.



Some of the materials that can be dated by thermoluminescence.

Dating archaeological ceramics

The use of pottery, ubiquitous on most British sites, as a chronological marker is well established in archaeology. Along with other evidence, it provides a means of dating the estabishment and subsequent development of sites. Depending on the distinctiveness of the pottery and the major archaeological period, archaeologists have been able to construct ceramic chronologies. Although substantially 'floating' they have been, in certain cases, tied to an absolute chronology by association with other dating evidence with varying degrees of accuracy. For example, in the Roman period certain types of pottery can be dated within narrow limits by typology and associated dating evidence such as coins, whereas in the British Iron Age, particularly in north-east Britain, most pottery is of extremely rough quality and indistinctive for most of the period. For this period, excavated deposits frequently fail to yield potential dating evidence, other than pottery. In such cases the use of TL dating can provide an absolute date for the pottery artefact. Besides assisting in the formation of chronological frameworks for particular archaeological problems, the absolute nature of a TL date is important because it enables comparisons to be made independent of cultural influences.

Currently the best accuracy that can be achieved is in the region of ±5% of the TL age. Consequently there are archaeological periods where other techniques, such as carbon-14 dating, offer greater accuracy, and TL is not normally used if other dating material is available. The optimal periods for TL are the medieval period and the Iron Age where it has been able to make valuable contributions both in defining groups of pottery and in dating. Besides using such dates for resolving problems of site chronology, TL also aids the ceramic specialist who is interested in the development of form and technology.

Our specialist research experience gained in dating ceramics enabled the Durham group, in 1983, to launch a unique service for archaeologists and we now receive samples from many parts of the world.

Fundamental studies

To a large extent, the development of TL dating has been underpinned by an empirical approach. This has proved necessary because of the complexity of TL processes in natural materials and the lack of sensitivity of techniques normally used in defect research (about 10^6 luminescent events for a typical archaeological sample). However, studies of the effects of radiation of crystalline and amorphous SiO_2 used in electronic and optical devices has led to renewed interest in understanding the defect processes in such materials, particularly those that participate in TL and related phenomena.

Environmental dosimetry

The TL phosphors which are used for environmental and personnel dosimetry are several orders of magnitude more sensitive to ionising radiation than most natural TL materials used for dating. However, there are special environmental radiation problems where there was no planned dosimetry, but where TL minerals in the form of ceramic bricks and tiles were fortunately present during the irradiation event. If the age of such artefacts is known, radiation doses in addition to those accruing from natural sources can be determined using standard TL dating techniques.

One important application of this type of work has been the retrospective measurement of radiation dose at Hiroshima and Nagasaki; measurement of dose due to fall-out in the vicinity of the Nevada Test Site is another currently in progress.

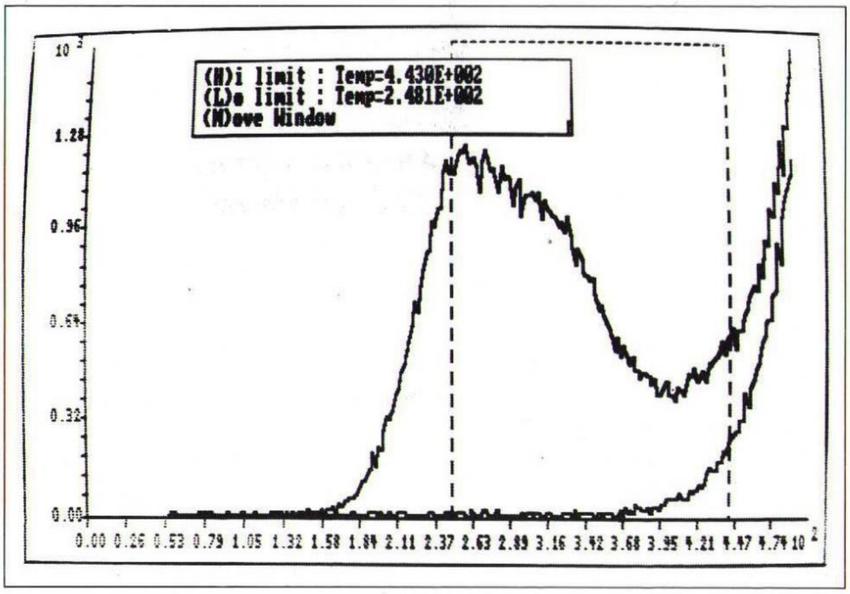
Following on from earlier measurements by Japanese TL workers, five TL laboratories, including our own, have contributed to an evaluation of absorbed gamma dose in bricks and tiles at various distances from the hypocentres at each location. The results, due to be published shortly, support an upward revision of dose predicted using the latest theoretical model. In the Nevada project it has been shown possible to measure gamma doses due to fall-out down to a level of about 10 mGy using brick samples from public and domestic buildings. For both studies, the techniques used were derived from those developed for ceramic dating.

Other work

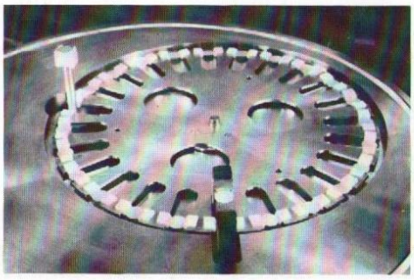
Our work on ceramics represents only part of the expanding TL research that is being applied to archaeological dating studies. Other heated materials of archaeological significance (eg flint, hearths, bricks, kilns and heated rock) have been dated by TL and are the subject of research within several active TL laboratories in the UK. TL has also been used in the study of meteor and lunar materials.

In the burgeoning field of sediment dating, the use of optically stimulated luminescence promises interesting developments in the future.

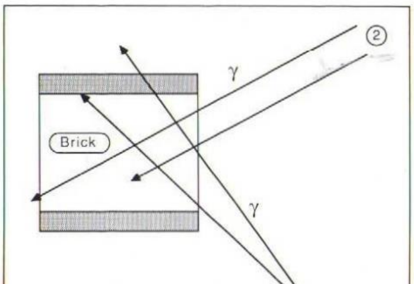
Ian Bailiff
Department of Archaeology
Durham University



A natural TL glow curve (taken directly from a VDU; the abscissa and ordinate represent temperature and TL intensity respectively) obtained from TL crystals which had been extracted from Iron Age pottery. The second curve, rising only at higher temperatures, is due to the black body emission from the heater plate. The glow curve data is subsequently filtered using FFT techniques.

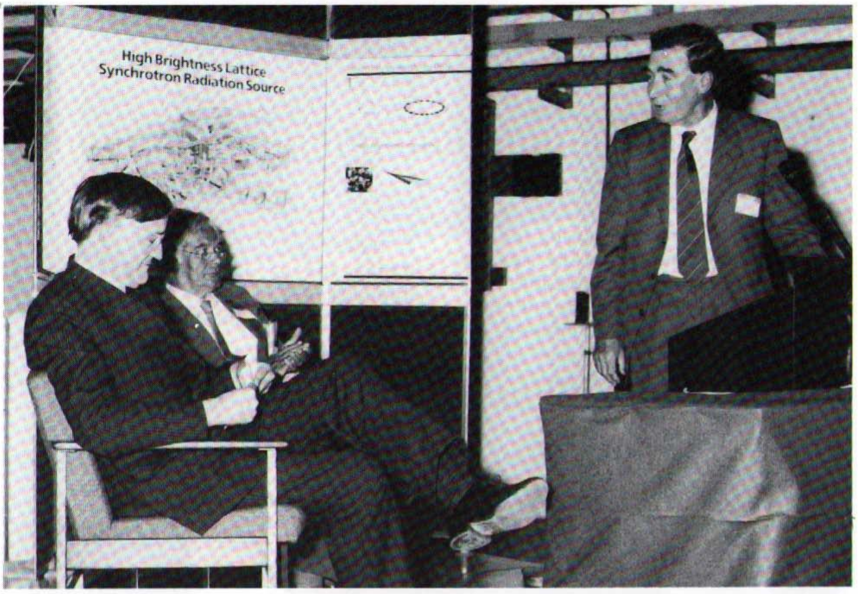


A view of part of the prototype automated TL reader, showing the 24-sample disc carrier and two discs that have been selected and raised, to enable heating of discs (foreground) and beta irradiation (left, rear). A cover plate seals the sample chamber and carries the TL detection system and beta irradiator housing.



Schematic diagram of two sources of gamma radiation (in addition to natural sources) that TL crystals within brick can measure; (1) from fall-out debris on ground and (2) direct radiation from blast.

Increased brilliance for SRS



Mr Robert Jackson, Parliamentary Under Secretary of State, Department of Education and Science, visited Daresbury Laboratory on 17 September 1987 and inaugurated the High Brightness Lattice Synchrotron Radiation Source. The HBL project has increased the brilliance of the SRS by an order of magnitude making it one of the world's best facilities for ultraviolet and X-radiation research with its increased brightness and greater spatial, temporal and energy resolution. During his speech, Mr Jackson referred to the accelerators at Daresbury as two spectacular examples of SERC's support for the academic research community. A lively press conference followed the inauguration ceremony after which Mr Jackson lunched with guests representing a wide spectrum of the user community on the SRS. Shown (left to right) are Mr Jackson, SERC Chairman Professor Bill Mitchell and the Director of Daresbury Laboratory Professor Leslie Green.

High-T_c superconducting database

A bibliographic database of published papers and preprints on the new high temperature ceramic superconductors has been developed at the Daresbury Laboratory. It became available to users through the Joint Academic Network JANET in July 1987 and at present the database has almost 1000 entries.

Known as HITC, the database offers fast retrieval of bibliographic information and allows logical manipulation of retrieved material and display of results. Searches can be undertaken on author name, title word, institute, journal, date of entry as well as for entries having a specified molecular formula or associated critical temperature within a range of values given.

Access to the database is primarily intended as a free service to academic users in universities and polytechnics, but commercial contacts from industry would be welcomed.

HITC is updated on a weekly basis with current and retrospective information from periodicals and abstracting services, together with entries that users may wish to add, such as preprint information.

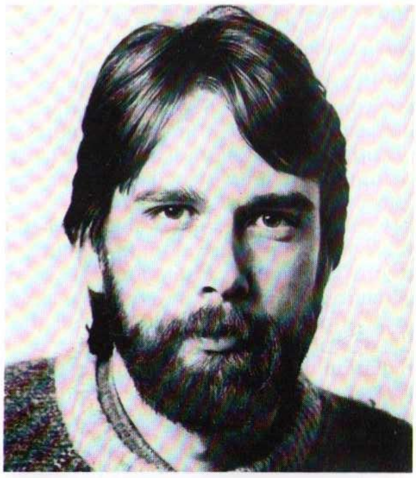
The database supplements the Rutherford Appleton Laboratory's HITC preprint service operated through the RAL library; Daresbury users may send preprints to the RAL service or obtain them from there.

A manual giving more comprehensive information about the database, together with further details about the service, is available from Dr Walter Temmerman or Ian Sharp at Daresbury Laboratory (telephone Warrington (0925) 603227 or 603519 respectively).

Coordinator for science-based archaeology

Dr Mark Pollard, of University College, Cardiff, has recently been appointed as National Coordinator for Science-based Archaeology. The post is jointly funded by SERC, the Historic Buildings and Monuments Commission and the British Academy. The aim of the appointment is to enhance liaison between the various funding bodies for Science-based Archaeology, to improve communication flow and to encourage the development and take-up of science-based techniques and results in archaeology. Dr Pollard will also act as an information dissemination focus for the Science-based Archaeology Committee, providing information on its policies and priorities. He will be visiting appropriate institutions, including universities, polytechnics, museums and units; and will be organising a series of workshops on various aspects of archaeological science.

Dr Pollard may be contacted at:
Department of Chemistry, University College, Cardiff, PO Box 78, Cardiff, CF1 1XL.
Telephone Cardiff (0222) 874210.



Dr Mark Pollard

New initiative in molecular electronics

SERC has recently announced an Initiative in Molecular Electronics with a budget of approximately £1 million a year. The purpose of the Initiative is to encourage the UK academic community to increase significantly its research activity in this exciting field and to promote the growth of multi-disciplinary groups. It is anticipated that a complementary joint SERC/Department of Trade and Industry programme under the LINK scheme will be announced in the near future.

Molecular electronics, which is the systematic exploitation of molecular, including macromolecular and biomolecular, materials in electronics and related areas such as optoelectronics, has evolved during a time of intense pressure from the microelectronics and optoelectronics industries for faster devices and for novel components for new system applications. As the perceived limitations inherent in silicon, III-V and other 'standard' electronic and optoelectronic materials begin to affect the realisation of advanced system designs, this pressure will grow and the demands on the scientific base will increase.

An azobenzene derivative showing nematic liquid crystalline behaviour in a polarising microscope. (Photo: Lancaster University).

The remit of the Initiative is the design, synthesis, full characterisation and study of molecules which, when aggregated, yield materials and films having active properties such as bistability, non-linearity or transduction in the optical or electronic domains. The Initiative will fund longer-term research directed towards the understanding of the highly complex organisational and functional properties of molecular systems encompassing both electronic and chemical pathways for pattern recognition and information processing. Support will also be provided for fundamental studies involving non-linear optical properties, liquid crystal behaviour, electrochromic and photochromic properties, piezoelectric and pyroelectric properties and electronic, photonic and ionic conduction.

A key quality required of researchers in molecular electronics is that they are prepared to work as part of a multi-disciplinary team, bringing the skills of, for example, physicists, chemists, biologists, materials scientists, electronic engineers and computer scientists to bear on both basic and strategic research projects. It is the intention of the SERC Initiative to promote such inter-disciplinary collaborations to help tackle the fundamental problems in the area.

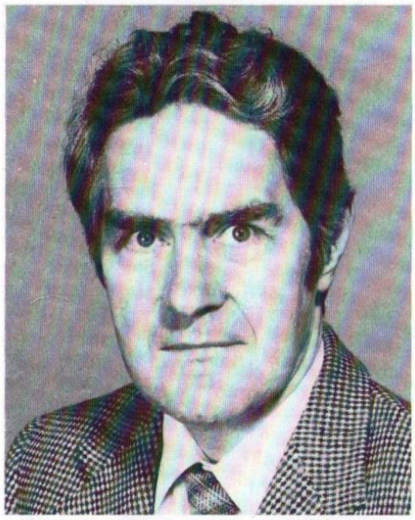
Molecular Electronics Committee

To oversee this initiative a new Molecular Electronics Committee has been established, chaired by **Dr Anthony Ledwith** of Pilkington plc. It has its own earmarked budget and will report to the Science and Engineering Boards. By providing a single focus for molecular electronics within SERC, the Committee will ensure that proper consideration is given to this multi-disciplinary area. It will monitor developments and stimulate research where necessary.

A Coordinator, **Professor David Bloor**, has been appointed to assist in the development of the Initiative. He will have particular responsibility to encourage and coordinate research activities leading to the establishment of strong multi-disciplinary groups.

Contacts:

Mr Stuart Ward, SERC Molecular Electronics Project Officer (Central Office, Swindon) or Professor David Bloor, Department of Physics, Queen Mary College, Mile End Road, London E1 4NS.



Professor David Bloor

New publications from SERC

SERC annual report

Report of the Science and Engineering Research Council for the year 1986-87 was published in November 1987. Copies are available from HM Stationery Office bookshop in Manchester or any bookshop, price £6.00, or through institution libraries (ISSN 0261-7005; ISBN 1 870669 00 2).

Particle physics

Copies of the *Particle Physics Committee annual report 1986-87* are available from Andy Thompson, SERC Central Office, Swindon, ext 2325.

Materials

Copies of two Materials Committee publications are available from the Committee Secretariat, SERC Central Office, Swindon, ext 2330. They are: *Current grants August 1987 and Annual report 1985-86.*

Electro mechanical engineering

The Electro Mechanical Engineering Committee has produced a leaflet, *Strategy of the Electro Mechanical Engineering Committee*, and two reports: *Current grants August 1987* and *Reports on projects 1987.* Copies of all are available from Mrs M Wilkes, SERC Central Office, Swindon, ext 2201.

European Science Foundation

How it works and what it does

The objectives of the European Science Foundation (ESF) are to bring together European scientists to work on topics of mutual concern, to coordinate the use of expensive facilities and to discover and define new endeavours that will benefit from a cooperative approach. The Foundation was set up in 1974. It is an international non-governmental organisation composed of 49 academies and research councils from 18 countries. The UK member organisations are the five Research Councils (Agricultural and Food; Economic and Social; Medical; Natural Environment; and Science and Engineering), the Royal Society and the British Academy. The ESF provides a forum where these member organisations are able to discuss common policies and joint activities.

The scientific work sponsored by ESF includes basic research in natural sciences, medical and biosciences, social sciences and the humanities. The interests of the European scientific communities in these fields (and space science) are monitored by the five Standing Committees of ESF. These Committees (each of which has a UK representative) report to the main executive and decision-making bodies of the ESF and are responsible for setting up specialist working groups on selected topics, and preparing and considering proposals for ESF activities.

Budget

All member organisations contribute to the ESF General Budget according to an agreed formula related to the net national income. This budget (which amounts to about £1 million a year) covers the central operation of the ESF headquarters in Strasbourg, including the Secretariats; about 10% of this is used to fund general scientific and planning activities. All other activities of the ESF are funded by special levy and fall into three main categories:

- *Additional Activities* are specific programmes with their own special budgets to which only those member organisations wishing to participate in the programme contribute. These are usually of five to seven years' duration and can include series of workshops, seminars and conferences; collaborative research projects; fellowships schemes; training activities; compilation of data to produce reports, books and data-bases.

In some cases, Additional Activities can be expected to lead to major international projects. This was the case with the Synchrotron Radiation Activity which, following the preparation of the scientific case and feasibility study, led to the current Agreement for the European Synchrotron Radiation Facility. Although it is within the remit of NERC rather than SERC, perhaps the best known Additional Activity running currently is the European Geotraverse, in which researchers from 13 countries combine to explore, through various techniques, the structure of the European Lithosphere, along a line from the north cape of Norway down to Tunisia.

- *Associated Programmes* are similar to Additional Activities in their aims, execution and funding except that overheads and staff effort are charged to the Associated Programmes budget to which all participating member organisations contribute. An example is the Ocean Drilling Programme which has led to a European Consortium — a new member of the world-wide programme for ocean drilling.

- A new form of activity known as *Scientific Networks* was introduced in 1985 following a Council of Europe Conference of Ministers in 1984. The purpose of Networks is to bring together ideas, effort, equipment, training and expertise in areas designated by scientists themselves as requiring action on a European level. Networks are initially funded for two years, from a central Seed Fund to which all member organisations contribute. Networks should strengthen and consolidate the community in a specifically defined area and they are intended to be self-managed from within the scientific communities. In some cases, Networks may develop into major collaborative projects. Some ten Networks have been started in the first two years of this effort.

- In addition, ESF runs a number of *ad hoc* activities which are inexpensive and not as formalised as requiring a special budget.

Future prospects

The UK member organisations are anxious to maintain the current level of UK involvement in ESF activities provided that areas can be identified which fall within the objectives and modes of operation of the Foundation and meet real needs in the European scientific community; for example, areas in which European scientists might be particularly well placed to excel; areas which are not well developed and are in need of stimulation or areas which would give far better value for money if developed cooperatively for Europe as a whole rather than within narrow national frontiers.

Funding for the ESF, as for all other science in Europe, is tightly constrained and activities highly selective. The money comes from the member organisations and in the UK all contributions are from existing budgets: the government provides no additional funds for in ESF activities. Participation is encouraged where this could help to maintain standards, to add creativity by generating cross-fertilisation of ideas between internationally based groups and lead to more cost effective ways of working.

Bearing in mind the UK funding position, members of the UK scientific community are invited to consider specific areas of interest which might be appropriate for development through ESF action, putting emphasis on a European dimension and bringing together the efforts of individual groups.

Recent past and current activities of ESF witnin SERC's remit

Synchrotron radiation (AA)	1976 - 1982
Polymer science (*ad hoc*)	1979 - 1986
Archaeology (*ad hoc*)	1980 - 1984
Taxonomy Project I: European Taxonomic, Floristic and Biosystematic Documentation System (AA)	1981-1987
Project III: European Plant Parasitic Nematode Survey (AA)	1981 - 1986
Planning Committee on Technology Assessment (*ad hoc*)	1981 -
Atmospheric chemistry workshops (*ad hoc*)	1985 - 1987
Chemistry and physics of polymer surfaces and interfaces (AA)	1986 -
Crystallography of biologically important molecules (Network)	1987 - 1989
Surface crystallography (Network)	1987 - 1989
Non-linear sciences planning workshops (*ad hoc*)	1987 -

Further information about these activities, as well as copies of *About the European Science Foundation* and the journal of the ESF, *ESF communications,* can be obtained from ESF, 1 quai Lezay Marnesia, F-67000 Strasbourg, France (telephone 010 33 88 35 30 65), or from International Section, SERC Central Office, Swindon (ext 2404).

SERC enquiry points

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

ASTRONOMY AND PLANETARY SCIENCE DIVISION

International activities	Dr A Game ext 2417
UK activities	Mrs D C Herbert ext 2365
Research grants	C G Brooks ext 2359
PATT awards	Mrs A T Bratko ext 2198
Studentships and fellowships	N R Mayl ext 2267

BRITISH NATIONAL SPACE CENTRE

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

Space Science Programme Board

UK activities	Dr R L T Street CO ext 2265
Research grants	J E Palmer CO ext 2359
International activities	MT ext 7290
Microgravity	Ms J S Williams MT ext 4855
ESA fellowship scheme, Young Graduate Trainee scheme	D Peters CO ext 2219

Earth Observation Programme Board

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

ENGINEERING DIVISION

Medical engineering	Dr C Rapier ext 2110
Materials	D Mullins ext 2338
Environment	Dr C Marsden ext 2353
Civil engineering	N L Williams ext 2155
Process engineering	Dr R K Burdett ext 2101
Aerospace	N H J Birch ext 2103
Electrical and power	C P Whitlock ext 2350
Machinery, plant and vehicle	Miss P A Rogers ext 2117
Joint ESRC-SERC; studentships & fellowships	Dr M Wilson ext 2238
Information dissemination	D Harman ext 2429
Design	A Spurway ext 2102

DIRECTORATES

ACME (including manufacturing processes)	T J Keaney ext 2106
Teaching Company	Miss K Enifer ext 2165
Biotechnology	Mrs A Williams ext 2310

Information Technology

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

The Marine Technology Directorate Ltd
2 Little Smith Street, Westminster, London SW1P 3DH; telephone 01-222 7331.

NUCLEAR PHYSICS DIVISION

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

SCIENCE DIVISION

Biological sciences	Dr P W H Fletcher ext 2136
Mathematics	F Hemmings ext 2312
Neutron facilities; laser facility	M J Hotchkiss ext 2222
Physics	J Farrow ext 2261
Science-based archaeology	Mrs F Clouder Richards ext 2361
Chemistry	Dr P Sharma ext 2496
Synchrotron radiation facility; computing	Dr J O Wand ext 2113
Pharmacy	Dr G Ll Richards ext 2323
Molecular electronics	A G Buckley ext 2166
Cooperative grants (Science)	Ms S A Robertson ext 2214

FINANCE

Account queries	T A Treglown ext 2434

RESEARCH GRANTS

Most enquiries should be addressed to the appropriate subject committee.

Terms and conditions; supply of forms	ext 2405

STUDENTSHIPS

Applications

Advanced course studentships	ext 2414
Research studentships; Studentships tenable abroad, including NATO	ext 2316
CASE and general enquiries	ext 2138

Current awards

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

FELLOWSHIPS

Postdoctoral (home, overseas and NATO), advanced and senior fellowships	ext 2172/2403
Royal Society/SERC Industrial	ext 2206/2352
Anglo-Australian Fellowships: K B Maunders, Royal Observatory, Edinburgh	031-667 3321 ext 249
CERN	ext 2325
ESA	ext 2219

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

INTERNATIONAL COLLABORATION

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

CENTRAL COMPUTING

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

LINK

S D Ward ext 2173

SERC BULLETIN / PRESS ENQUIRIES

SERC BULLETIN	ext 2120
PRESS ENQUIRIES	exts 2257, 2256

Complex Stochastic Systems

The SERC initiative

Technological developments in automated data collection and processing, together with related developments in computer and telecommunications networks and automated reasoning processes, are resulting in increasingly complex systems and data structures, which pose novel problems of stochastic modelling, exploratory statistical data analysis and more formal statistical inference. These problems are described by Professor Adrian Smith of Nottingham University.

The new problems include: data visualisation; model fitting and validation; image analysis and pattern recognition; time series and signal processing; telecommunications networks; molecular population genetics; simulation; knowledge representation and expert systems. Fields of application include: archaeology, astronomy, chemistry, ecology, expert systems, geology, hydrology, medicine, meteorology/climatology, molecular genetics, oil exploration, pollution monitoring, remote sensing, speech technology, telecommunications and tomography.

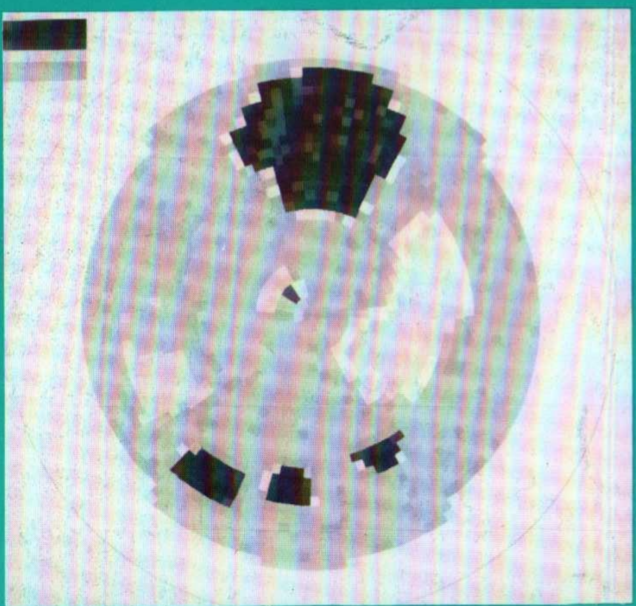
Ad hoc solutions are, perforce, being developed throughout science and engineering. What is needed urgently is for mathematicians and statisticians to take a broader view of the theoretical aspects of these topics, to subject existing methods to rigorous scrutiny, and to develop coherent strategies for the solution of current and new problems. The UK is fortunate in having a number of groups with international reputations in many of the areas mentioned above, but individuals are over-stretched both because of the complexity of the problems to be tackled and because of the need to develop basic research in addition to solving specific applied problems. In recognition of the timeliness and importance of these new directions in statistical research, the Science Board of the SERC has allocated additional funding to its Mathematics Committee to support research within the broad areas of activity outlined above.

As well as requiring traditional statistical and mathematical expertise, the basic research is typically highly computer-intensive, both in its need to visualise and explore complex data structures and in its need for mathematical experimentation in order to conjecture properties and understand models.

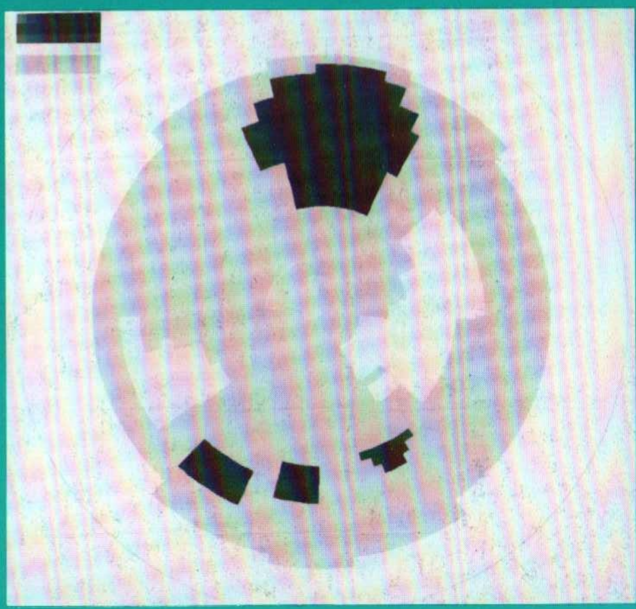
These activities require adequately equipped computer facilities, including fast interactive graphics, plus research assistants and students. In part, there is a need to support a small number of well funded centres in order to ensure a 'critical mass' of activity and the efficient use of dedicated computer resources. In addition, there is a need for support of smaller groups and individual mathematicians and statisticians working on either specific applied problems or on related basic research.

Industry, particularly in its research divisions, has an increasing need for statisticians with experience in complex stochastic systems and encouragement for this initiative has been received from the chemical, pharmaceutical and petrochemical industries, as well as from telecommunications, systems analysis and expert systems companies. The increase in trained personnel resulting from the initiative will prove of direct benefit to industry. In addition, the build-up of well equipped academic centres of excellence will open up new possibilities for CASE projects and collaborative research programmes.

Professor A F M Smith
Department of Mathematics
Nottingham University



A stage in reconstructing an image from positron emission tomography, using a radial cell array and computer-intensive statistical estimation techniques applied to a mathematical model of the imaging process.



A smoother version of the same image. (Graphics: Bath University).