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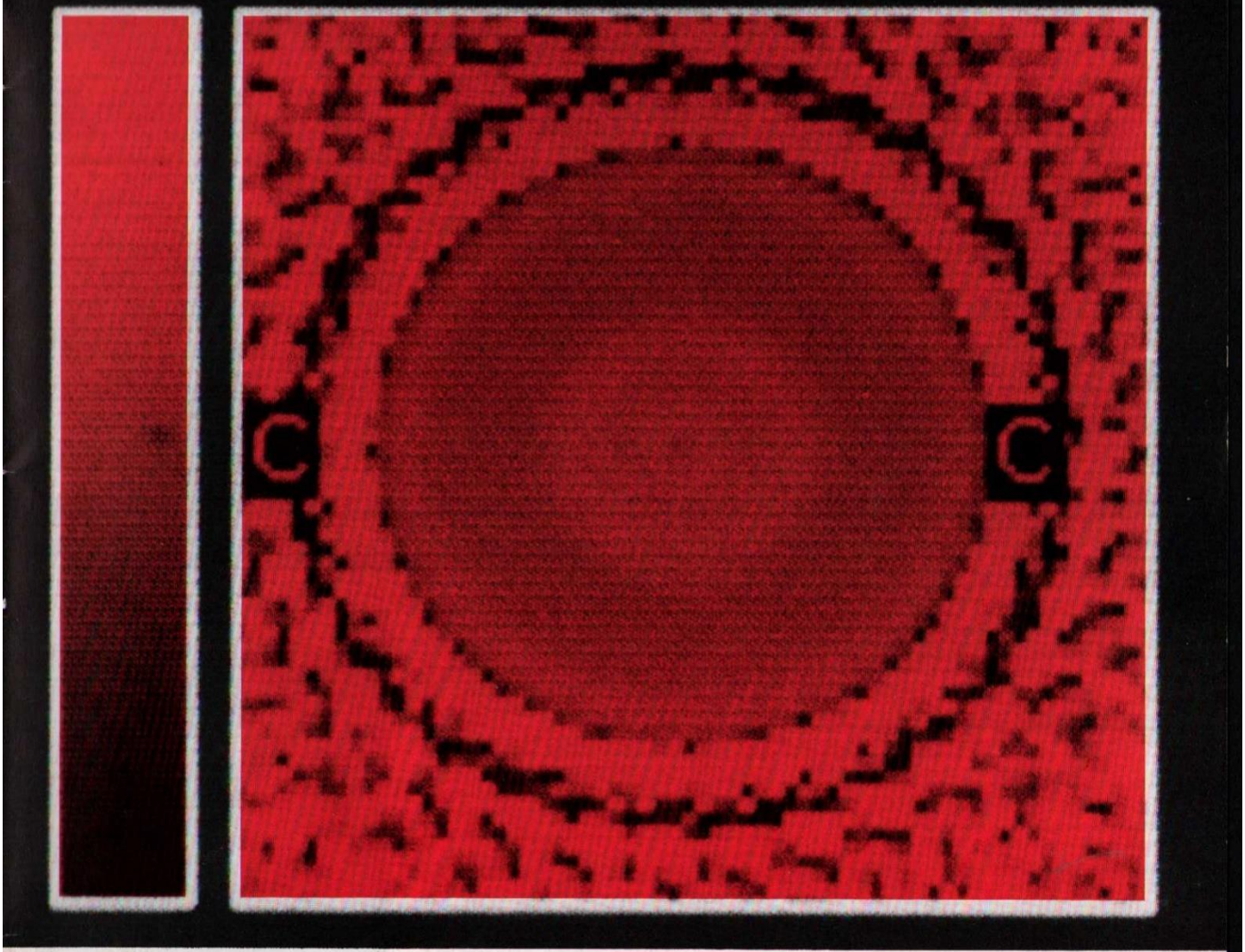

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The Science and Engineering Research Council is one of five research councils funded through the Department of Education and Science. Its primary purpose is to sustain standards of education and research in the universities and polytechnics through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

***SERC Bulletin* summarises the Council's policies, programmes and reports.**

Enquiries and comments are welcome and should be addressed to the editor, Miss J Russell, at the Science and Engineering Research Council, Polaris House, North Star Avenue, Swindon SN2 1ET; tel Swindon (0793) 26222.

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New Council Member appointed

Dr Carole Jordan, an astrophysicist at Oxford, has been appointed by Sir Keith Joseph, Secretary of State for Education and Science, to the Science and Engineering Research Council. Dr Jordan fills the Council seat left vacant by Professor Bill Mitchell on his appointment as Chairman of the Council. Her appointment runs until 31 July 1989.

Carole Jordan gained a PhD in solar physics from London in 1965 and spent the following year as a research associate at Boulder, Colorado, USA. She then joined the Spectroscopy Division at UKAEA, Culham Laboratory, which evolved into the newly-formed Astrophysics Research Unit within the (then) Science Research Council at Culham in 1969. She took up her present post at Oxford, as Wolfson Tutorial Fellow in Natural Science at Somerville College, and University Lecturer in the Department of Theoretical Physics, in 1976.

Dr Jordan has done extensive work with the International Ultraviolet Explorer since its launch in 1978, mainly working on cool stars. She is a co-investigator with the X-ray polychromator instrument on the Solar Maximum Mission; and a co-investigator both with the US High Resolution Telescope and Spectrograph flown with Spacelab 2 in July 1985, and with the Ulysses (solar heliospheric) mission to be launched later this year.

Dr Carole Jordan

She is Chairman of the Solar System Committee of SERC's Astronomy, Space and Radio Board, of which she is currently a member; Secretary of the Royal Astronomical Society and a member of its Council; and has served on various advisory committees of the European Space Agency, NASA and SERC.

University Chair for Industrial Fellow

Professor A J Rogers, formerly of Central Electricity Research Laboratories (CERL) at Leatherhead, who held a Royal Society/ SERC Industrial Fellowship from September 1981 to February 1983, has been appointed to the Chair of Electronics at King's College London. An optoelectronic facility at KCL was set up as a consequence of Professor Rogers's fellowship and is now well established. The facility has taken up a number of research initiatives in the optoelectronics area, including a study of non-linear optical effects in optical fibres and basic research in the area of distributed optical fibre measurement sensors. Close links have been retained between King's College and CERL, which has a significant input into the undergraduate programme at KCL.

Further details of Professor Rogers's industrial fellowship and on the scheme in general were given in *SERC Bulletin* Volume 2 No 12, Autumn 1984.

Professor A J Rogers

Front cover picture

Microwave measurement of dielectric loss within a composite cylinder, from diffraction tomography studies at Sheffield University. ***See page 14.***

Council Commentary

Council Commentary

At its October 1985 meeting Council discussed its annual estimates for 1986-87 in preparation for their submission to DES. The ABRC had made an additional £1.85 million available from its flexibility margin, of which £1.2 million was allocated to the Alvey programme with the balance going to the Science Board. Council also discussed the timetable for the submission of the Forward Look and invited its Boards to make bids against the agreed allocations.

Kendrew Report

Council noted the Nuclear Physics Board's reactions to the Kendrew Report, which had recommended a cut of 25% in the budget for particle physics by 1991. The NP Board had endorsed a resolution by the European Committee for Future Accelerators which considered the proposal incompatible with the aim of ensuring that research of world class is continued at CERN.

Advanced research computers

The recommendations of the Report of the Working Party, set up by the ABRC, the UGC and the Computer Board, to consider future needs for advanced research computing, were discussed at the October Council meeting. The Report recommended that funds should be sought for a national facility and that a new body should be established to advise the principal funding agencies and to regulate and coordinate the use of the facility. Council welcomed the proposal that it should be responsible for operating the proposed machine, and agreed with the importance ascribed to the facility for future research in science and engineering. The Council's views would be put to ABRC in January 1986.

Condensed matter research facilities

In addition to the 'internationalisation' of ISIS, the spallation neutron source at Rutherford Appleton Laboratory (see page 4), the Science Board had recommended to Council that it should participate in Phase B (the design study phase) of the European Synchrotron Radiation Facility (ESRF), at a cost of £350,000 in 1986-88. The ESRF would be a hard X-ray machine of high intensity, and promised many scientific benefits. Council endorsed the Science Board's proposals and DES approval will be sought.

Training awards for 1986

Council approved the Boards' planned support for postgraduate studentships next year. The most significant change compared with last year is an increase in the number of awards for students on MSc courses in information technology.

British National Space Centre

Council was pleased to receive news of the appointment of Mr Roy Gibson as first Director-General of the newly-created British National Space Centre. SERC intends to play a full part, along with its partners, in developing the Centre's programme; a formal decision on participation is to be taken early in 1986.

Select Committee Report on the Science Budget

The House of Commons Select Committee report on *The future of the Science Budget* was discussed by Council, which noted with agreement the recommendation of a 3% growth in the Science Budget over and above inflation.

Major New Grants approved by Council

SCIENCE

Professor R A Stradling and Professor D W Pashley (Imperial College of Science and Technology): special rolling grant of £811,000 over four years as part of the Low Dimensional Structures Programme.

Professor S D Smith and Professor E W Laing (Heriot-Watt and Glasgow Universities): a revised grant of £151,300 over 12 months extending the programme on UK free electron laser development.

ENGINEERING

Professor R T Severn, Dr A R Blakeborough and Dr C A Taylor (Bristol University): £473,154 over three years for research on the creation of a six-axis shaking table for earthquake engineering research (see page 22).

BIOTECHNOLOGY

Professor P Dunnill and Dr M Hoare (University College London): £330,800 over four years for a biochemical engineering study to improve protein processing and stability.

INFORMATION TECHNOLOGY

Professor K G Stephens (Surrey University): £633,174 over four years for the Surrey Ion Beam Facility for Microelectronics.

Professor H A Kemhadjian, Dr A Brunnschweiler, Dr J G Smith (Southampton University): £841,679 over three years for the Silicon Central Microfabrication Facility.

Dr R J Robertson, Dr A J Walton, Dr R Holwill, Dr J R Jordan, Dr M A Jack, Professor J Mavor (Edinburgh University): £848,844 over three years for development and support for the Edinburgh Microfabrication Facility.

Professor P N Robson, Dr P A Houston (Sheffield University): £1,020,260 over four years for support and development of the III-V Central Facility.

Joint Research Council/Ministry of Defence research grants

Arrangements for research grants jointly funded by the Research Councils and the Ministry of Defence were announced on 4 November 1985 by Mr Norman Lamont MP, Minister of State for Defence Procurement, with Mr Peter Brooke MP, then Parliamentary Under Secretary of State at the Department of Education and Science. The grants aim to support research which is not only of high academic quality but also likely to be relevant to defence, thereby contributing to the strengthening of both the UK science base and the defence research programme. The Government's intention to support research in the universities and other institutions of higher education in this way was announced in the Statement on the Defence Estimates 1985. Information about these joint research grants and how to apply for them is contained in a brochure, copies of which have been distributed to the administrative offices of academic institutions.

SNS becomes ISIS

Arriving for the inauguration and naming ceremony: the Prime Minister with the SERC Chairman Professor Bill Mitchell and, behind, Sir Keith Joseph, Secretary of State for Education and Science, and Dr Geoff Manning, Director of RAL.

Looking down over the synchrotron ring, Dr Bruce Forsyth explains how the machine works to a group of European ambassadors, ministers and other distinguished guests.

Mr David Gray describes some of the synchrotron components to distinguished guests including the Netherlands Ambassador Mr J L R Huydecoper; Minister of State for Industry and Information Technology Mr Geoffrey Pattie; and Mr Peter Brooke, then Parliamentary Under Secretary for Education and Science.

On 1 October 1985 Prime Minister Margaret Thatcher inaugurated and gave the name ISIS to the spallation neutron source sited at the Rutherford Appleton Laboratory. The pulsed neutron facility is for the study of condensed matter, and its science programme is now well under way.

As the Prime Minister pointed out, ISIS is the largest facility built wholly by the Council. "It has taken seven years to build and cost £60 million and was worth every penny," said Mrs Thatcher.

Mrs Thatcher emphasised that interest had been shown in the project both from other countries and from industry. "This was further evidence that we have a winner — we have got it right," she said.

Professor Bill Mitchell, on his first day in office as Chairman of SERC, told the audience that he was certain that the new machine would bring about great strides in our understanding of how matter was stuck together. Whether it was crystalline, glassy or liquid, neutron scattering methods could explain the atomic arrangements of these substances. "In the study of imperfections," he said, "we can follow, with neutron scattering, the process of the weakening of alloys and the atomic integrity of welds."

ISIS has been producing neutrons since the end of 1984 when the first pulses of neutrons produced data on new phenomena not seen before in neutron scattering experiments (see *SERC Bulletin* Vol 3 No 2, June 1985).

Since then, the power of the machine has been gradually increased until at the time of the inauguration and naming it was running at 5% of total power and by now it should be up to about 10%, with eight or nine neutron scattering experiments providing data.

International aspects

Links had already been established with West Germany through the KARMEN project which is built next to the ISIS station. KARMEN is an acronym for Karlsruhe Rutherford Medium Energy Neutrino experiment. It is sited at RAL because ISIS is, at present, the only source in the world for pulsed neutrons.

India has already provided a novel detector for one of the instruments, IRIS, already installed on ISIS, and collaboration with Italy for a new type of spectrometer is being discussed. Possibilities of using muon beams to study condensed matter are under discussion with the EC, France and West Germany. And, from outside Europe, Australia and Japan have also shown interest in joint ventures.

Science Board reviews its special initiatives

At its October 1985 policy meeting, the Science Board reviewed its special multidisciplinary research initiatives and received proposals for additional initiatives. It agreed that the existing programmes in low dimensional structures, protein engineering and chemical sensors (see *SERC Bulletin* Vol 2 No 12, Autumn 1984) should continue, and assigned a 'forward look' to each. It also agreed to set aside funds for new grants-funded programmes in non-linear systems (proposed by the Mathematics Committee) and for image interpretation and invertebrate neuroscience (proposed by the Biological Sciences Committee). These programmes will be backed by grant commitment allocations of up to £5.7 million in the 1985-86 academic session, with a small increase in prospect during the following four years.

The Board intends to review its portfolio of special grants-funded initiatives annually, and has set aside a small reserve to enable it to respond to changing requirements and for possible new programmes. In the latter category the Board encouraged the Biological Sciences and Chemistry Committees to undertake some further development of their proposal for a joint initiative in molecular recognition and biological specificity.

Non-linear mathematics

Non-linear systems not only offer exciting research to mathematicians but an understanding of them is essential in many fields of application, for example turbulence over aerofoils, meteorological models, elastic and plastic deformations, laser devices and population dynamics. In 1985-86 initial support will be given to a few major centres, one with an associated experimental laboratory. The programme includes the following research topics:

- Partial differential equations;
- Studies of solitons and integrable systems, eg interaction of propagating waves;
- Iterations on maps and the chaos occurring there;
- Rigorous mathematical and experimental approaches to a specific dynamical system, eg Taylor vortex motion.

Image interpretation

The understanding of the workings of the human brain is one of the big challenges in biology today. Image interpretation is concerned with how the brain's visual system recovers useful information from a retinal image in order to guide a response to a changing scene. The system has to be able to detect, discriminate and interpret intensity changes, surface features, edges and two- or three-dimensional features.

Biological information will underpin advances in engineering systems, such as the extraction of useful data from noisy data; coding and storing and reproduction of TV images; designing high resolution graphics displays; and the development of intelligent machines able to recognise and assemble components. (See also *New publications,* page 26)

Invertebrate neuroscience

Neuroscience embraces the study of the nervous systems of animals, including humans. The research ranges from molecular to cellular to behavioural and psychological and crosses the disciplines of biology, chemistry and physics. Because the human nervous system is extremely complex, the present five-year initiative will concentrate on the simpler invertebrate systems allowing, for example, detailed analysis of neural circuits and identifying the neuronal architecture underlying behaviour. In addition to the intellectual challenge and the long-term benefits from an increased knowledge of how the human brain functions, there will be industrial benefits such as the production of improved pesticides and the development of antiparasite drugs. (See also *New publications,* page 26)

Low dimensional structures

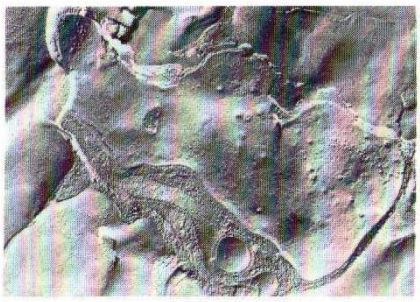
To date some £4.8 million has been committed under the LDS initiative, principally for the establishment of four growth centres at Nottingham, Cambridge, Oxford and Hull Universities. The first three of these will prepare systems based on the III-V materials (eg GaAs, InP), while at Hull magnetic superlattices of II-VI materials (eg CdTe, CdMnTe) will be grown and studied. Extensive industrial support is being provided through Cooperative Research Grants, CASE awards, etc and is already in excess of £2 million in value. Professor John Beeby of Leicester University has been appointed Programme Coordinator (see *SERC Bulletin* Vol 3 No 3, Autumn 1985).

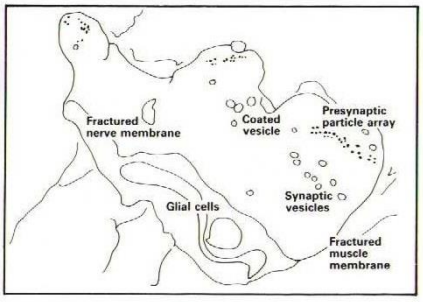
Protein engineering

Already some £2.5 million has been committed to protein engineering in fields related to protein crystallography. It is hoped to turn now to physical studies of proteins in solution, structural studies by NMR, fluorescence, etc, and studies on denaturation and renaturation. There is progress to be made in the methods of site-directed mutagenesis and isolation of clones, control of gene expression and recovery of mutant proteins. There are short-term benefits, including alterations in the specificity and thermal stability of small enzymes or hormones, and more ambitious long-term objectives such as changes in the functional properties of food proteins, structural proteins for fibres and textiles.

Chemical sensors

The chemical sensors initiative was established with the aim of improving fundamental understanding of sensor systems and developing new sensor devices. This is based on the formation of a number of multidisciplinary centres, several of which have already been funded. A Molecular Sensors Steering Group has been formed to coordinate the sensor interests of the Chemistry Committee, Biotechnology Directorate and Medical Engineering Subcommittee. The Group is developing a number of links with other interested bodies, such as the Department of Trade and Industry.





Neuromusclar junction of the locust (Micrograph: Nottingham University).

Waveform recognition in weakly-electric fish

Weakly-electric fish are abundant in the tropical freshwater habitats of Central and South America, Central Africa and the Nile. It is 30 years since the unique electric sense of these animals was first described, but it was not until 1970 that the intriguing possibility of electric communication began to be investigated.

The two Orders of bony fish which are known to possess an electric sense are the South American Gymnotiformes (Knife fish) and the African Mormyriformes (Elephant nose fish and relatives). SERC-supported work at Sheffield University has been looking at electric communication of the gymnotid group both in the laboratory and in their natural habitat in the rivers of the rain forest and coastal savannah of French Guiana.

An electric sense

Weak electric discharges are generated throughout the lives of these fish from specialised electric organs in the tail. In the pulse gymnotid group the electric organ discharges (EODs) take the form of a brief pulse lasting only 1 to 2 milliseconds with a peak to peak amplitude of about 3 V. The EODs are produced continuously at repetition frequencies of between 10 and 100 Hz — the exact value depending principally on the species and motor activity of the individual. During the head-positive part of the EOD, current from the electric organ escapes through thousands of low resistance electro-sensitive pores in the anterior skin surface. These electroreceptors transduce the current into a neural spike code. The outward flowing current follows curved paths through the surrounding water, similar to those of a dipole field, and re-enters the fish's body at its tail. The whole situation then reverses for the negative phase of the EOD.

The exact shape of the field depends both on the conductivity of the water and the proximity of objects or non-conducting boundaries such as the walls of hiding places, water surfaces and river banks. The distortion of the field pattern informs the electrosensory system of the position, conductivity and relative movements of objects. Each EOD gives the fish a 'snapshot' electrical view of the surroundings, providing it with an active navigation system unmatched by its competitors in the nocturnal aquatic world.

Electric communication

Since electric fish are designed to detect their own electric discharges it is not surprising that evolution has exploited this ability for the purposes of communication between individuals; natural selection has considerably modified the electrosensory system producing both highly sensitive receptors (thresholds below 10 μV/cm field strength) and neural structures clearly adapted for communication. While the range of electrolocation is limited to, at best, 10 cm, the fish can communicate over distances of up to 3 m.

Work on the social behaviour of electric fish has shown that modulations of the interpulse intervals (IPIs) code messages of threat, submission and readiness to mate and are certainly involved in the long term aspects of both territorial maintenance and school cohesion. More recently, our attention has switched to the relatively *invariant* EOD waveform which is fixed for an individual for much of its lifetime. In nearly every case investigated there are species, sex and age cues within the pulse itself. The EOD is therefore rich in information potentially useful in a variety of social behaviours. Figure 1 shows the EODs of nine pulse gymnotids caught and recorded in the field. These species are sympatric; EOD recognition is thus likely to be very important in maintaining species isolation. Figure 2 shows the sex and age differences in *Hypopomus beebei*, which we encountered for the first time this year in French Guiana.

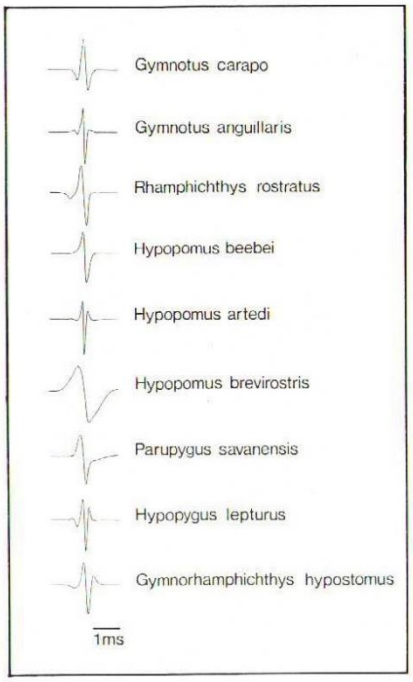


Figure 1. Electric organ discharges (EODs) of nine sympatric South American electric fish. The pulses are produced continuously from specialised tail organs at rates of between 10 and 100 Hz. The EODs are plotted from digital field records sampled at 1 MHz. Head positivity is upwards.

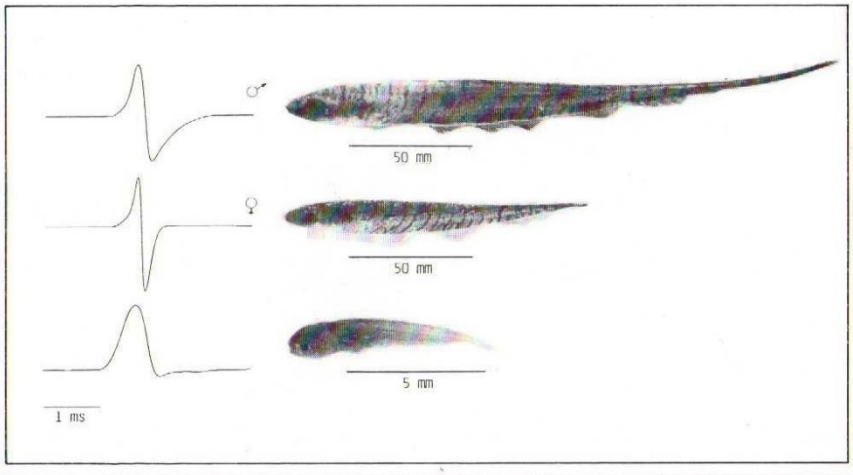


Figure 2. Discharge waveform is also sex and age specific, as seen here in the species Hypopomus beebei. *Recordings were made in the field near Kourou, French Guiana. Note that the larger male fish has a longer duration negative EOD phase. The monophasic larval discharge was produced by animals only 8 mm long, probably about 2 weeks old.*

Waveform recognition

How could the fish's electrosensory system analyse such brief waveforms? This is the question that we are currently investigating in collaboration with Carl Hopkins of Cornell University, USA. The best candidate for a waveform recognition mechanism has, for a long time, been taken to be the frequency tuning of the electroreceptors which, like their hair-cell descendants in the mammalian inner ear, act as band-pass filters tuned to the peak spectral power of the EOD. They could therefore be used either as a simple filter, maximising sensitivity to the species-specific EOD, or else, in conjunction with other receptor types, tuned to different parts of the frequency spectrum in a manner analogous to a three-cone colour vision system. Although the latter idea is very appealing, there is no electro-physiological evidence for frequency channels in the gymnotid electrosensory system. Another problem is that the power spectra of the sympatric species (with the exception of *H brevirostris*) are all very similar with a peak power of around 1.4 kHz.

We therefore wondered if there was a physiologically plausible way in which the fish could analyse the waveform in the 'time domain'. When *we* look at the shape of the EOD (as in figure 1), we discriminate the pulses on the basis of features such as the number and relative size of the different phases, their durations, inflexion points and so on. The spike code generated in the sensory cell and transmitted to the fish's brain simply relates the number of nerve impulses to the maximum peak-to-peak amplitude of the pulse. Unfortunately, there is only one receptor spike burst per EOD and so none of the above waveform characteristics can be seen in the neural response. Given this limitation, how could a temporal analysis of the waveform be carried out?

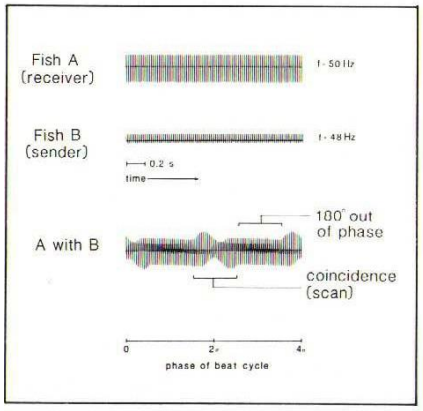


Figure 3. The beat pattern generated by the interference of two pulse trains of slightly different frequency. In this simulation the pulses are single-cycle sine waves. As the pulses 'slide through' each other at coincidence the peak-to-peak amplitude of the receiver fish's EOD is modulated in a manner dependent on the waveforms of the two fish.

Scan sampling

We have proposed a novel mechanism for waveform analysis, which we call 'scan sampling', which overcomes the problem inherent in the physiological processing of very brief waveforms, while exploiting the extreme sensitivity of the receptors to peak-to-peak amplitude change. The basic idea is that the receiver fish analyses the interference, or 'beat', pattern produced as the pulses of the foreign (sender) fish interact with its own. Figure 3 illustrates what happens in a simulated interaction between two pulse gymnotids, each having an idealised sinusoidal waveform. The 2 Hz difference in the repetition rate of the two pulse trains means that twice a second the pulses 'scan' through each other. Throughout the IPI the receiver fish's EOD is unaffected by the sender, but during the scan the pulse components add algebraically, producing a varying voltage pattern. The peak-to-peak amplitude therefore varies in a characteristic pattern, the shape of which depends on the waveforms of the two EODs. It is easier to see what is happening in the three-dimensional plot of figure 4. In this diagram the section of the receiver fish's interpulse interval, in which there is no scanning, has been ignored and successive EODs have been aligned in a window which shows what happens in the two milliseconds preceding and following each discharge. The slightly lower frequency S_2 pulse train scans the receiver's (S_1) pulses from left to right. The cycle of destructive-constructive-destructive interference can clearly be seen. Our current working hypothesis is that the fish recognises the changes in the neural firing rate produced as the foreign pulses ride on top of its own, and uses this pattern, which is unique for each species combination, as the basis of its waveform recognition system. Such a mechanism has the distinct advantage that now the species-specific pattern is massively stretched out compared to the duration of the EOD, thereby giving the central nervous system the time to detect important features. If, for example, overlap occurs for ten successive EODs of a typical species then the pattern will last approximately 200 ms compared to the 1 ms of the EOD itself. The smaller the frequency difference the more the pattern is stretched out and the greater the number of sampling points available to the receiving fish. The resolution of the interference pattern therefore increases with decreasing frequency difference of the two EOD trains.

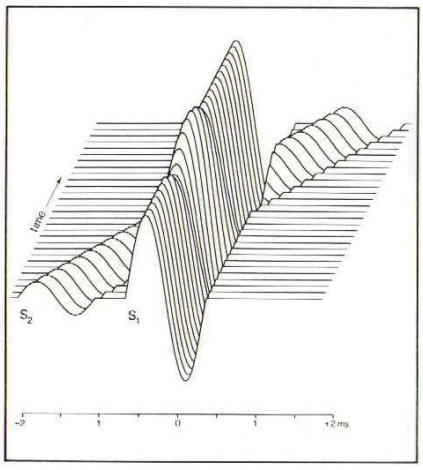


Figure 4. The peak-to-peak amplitude of the receiver fish (S_1) is only modulated when the foreign (S_2) pulse train overlaps with its own. The simulated fish S_1 is discharging a 1 ms duration EOD at 50 Hz while the S_2 train is generated at a lower frequency (49.75 Hz). The S_2 pulses therefore advance 0.1 ms per S_1 cycle producing a 'left-right' scan. By aligning all the S_1 pulses the exact form and duration of the modulation pattern can be visualised.

The scan sampling hypothesis generates a number of predictions which we are currently testing. One line of investigation has been to look at the electrical behaviour of fish in the field, in situations where we would expect waveform recognition to be useful. In order to gain complete control over the situation we used a microprocessor-controlled artificial fish-pulse generator which accurately mimics a real animal. The pulse train is played back through the electrodes of a model placed in the territory of a resident fish so as to simulate an approaching intruder. If the scan-sampling hypothesis is correct we would expect the resident to attempt to match its discharge rate to that of the model and introduce a slight frequency difference. Computer analysis of the field recordings looked for synchronisations and scans and compared the findings with control data. The results so far are very encouraging. We have found slow scans regularly occurring when test fish are presented with simulated intruders.

The results of these and similar experiments are now producing increasing support for scan sampling in electric fish and could, we believe, have implications for theories of waveform recognition in other species and modalities — including human speech processing.

G W Max Westby and Deborah K Shepperd

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Sheffield University

Two UK Spacelab experiments

The Spacelab 2 Mission which, after several hitches, was finally carried out successfully in July 1985, had on board three SERC-supported experiments, including the Coronal Helium Abundance Spacelab Experiment (CHASE) and the Coded Mask X-Ray Telescope (XRT) (See *SERC Bulletin* Vol 3 No 3, Autumn 1985).

The Coded Mask X-Ray Telescope

Briefly, the XRT consists of a pair of coded mask or transform telescopes supported on an alt-azimuth mount so that they may point at sources with a degree of independence of the Shuttle attitude. The telescopes are provided with a rather sophisticated attitude system based on TV and film cameras and a set of high quality gyroscopes. This allows the pointing direction to be determined to better than 30 arc seconds sufficiently often to correct for drifts and jitter in either the mounting or the Shuttle.

A coded mask telescope uses as the imaging element a metal screen with a suitable pattern of holes etched in it. The hole size is large compared with the wavelength of the radiation for which an image is required, so diffraction is negligible and a shadowgram of the scene is recorded on the large, position sensitive, X-ray detectors at the other end of the telescope. The shadowgram is transmitted to the ground (photon event by photon event) and an image reconstructed by computer analysis. This system will function at any wavelength where photons can be absorbed; in particular at X-ray or gamma-ray wavelengths where refraction or reflection take place with very low efficiency, if at all.

The XRT is designed to image celestial sources in the quantum energy range 2.5 to 25 keV. The two telescopes have angular resolutions of 3 and 12 arc minutes and a geometric detector area of 1024 cm^2 each. The results are expected to be complementary with those obtained from grazing incidence telescopes such as those on the Einstein and Exosat observatories, which operate below 2.5 keV. This higher energy range is important because
(a) The temperature of the intergalactic gas in galaxy clusters, one of our prime objectives, is generally between 2 and 10 keV, so the temperature is only well-determined by observations above 2 keV;
(b) The cosmically-important element Fe has a strong emission line in this range, near 7 keV; and
(c) Observations above 10 keV may yield information on non-thermal emission due for example to inverse Compton emission from energetic electrons and the microwave background.

Our entire system, both on the ground and in orbit, worked extremely well. The attitude TV camera proved to be slightly de-focused and suffered some performance loss in consequence, but in compensation the film camera performance was considerably better than we had anticipated. The sensitivity and imaging quality of the telescopes appears to be well up to the predicted values.

The Birmingham group consisted of 13 in all, divided into two teams, led by Dr G K Skinner, who was also the Project Scientist, and Dr C J Eyles, which operated 12-hour shifts. The crew on board had relatively little to do with XRT, nearly all its operations being conducted from the ground. Our team on duty was housed in the Payload Operation Control Center, adjacent to the Mission Control Center in Johnson Space Center, Houston.

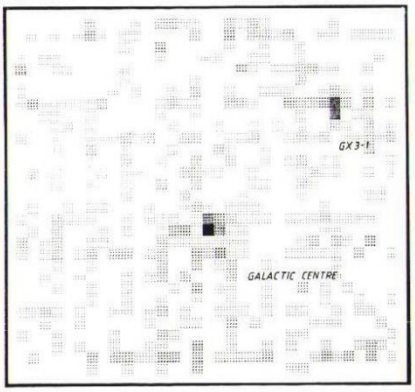
Reconstruction of the coded mask images is by no means a trivial task, when allowance is made for the various corrections necessary. Nonetheless, we had sufficient computing power available to produce 'quicklook' images, if the telescope performance was close enough to the nominal. About a day into the mission, on our first attempt to re-construct an image, we succeeded to our great delight in recording two bright sources near the Milky Way which we used as position calibration sources. Shortly afterwards, we imaged the Milky Way centre and a cluster of sources around it in a two-minute exposure. This is the first time that a truly imaging telescope has been used in orbit at these energies, and its performance is most impressive. It is also the first time that a coded mask telescope has been operated in orbit.

In all we obtained 75 hours or more of high quality observations. Our targets included eight galaxy clusters, the galactic centre and the region around it, the Vela supernova remnant and a variety of other sources, including calibration sources. Analysis of the data will take a year or more. The telescope arrived back in Birmingham in October 1985; NASA have offered to refly it in the autumn of 1987 and we hope to refurbish it for that purpose.

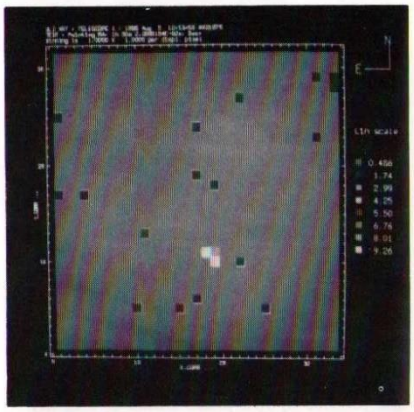
Rutherford Appleton Laboratory helped in several areas, making the thermal blankets for the telescopes and assisting with the detector calibrations, among other things, for which we are indebted, and obviously we are also tremendously indebted to NASA for the opportunity of the launch itself.

A P Willmore
Professor of Space Research
Birmingham University

The XRT installed on its pallet but with part of its thermal blanket removed, just before installation in the Shuttle.



A 'quicklook' image of the galactic centre (brightest pixel about 20σ, two-minute exposure); image obtained with the coarse telescope.



A calibration source, Vela X-1, exposed for 79 seconds in the coarse telescope, reconstructed and displayed on the Birmingham Starlink node. The source is divided between three light pixels. The dark spots are probably noise.

CHASE — The Coronal Helium Abundance Spacelab Experiment

The abundance of helium in the Universe is of great significance for cosmology in general and for our understanding of the early expansion that followed the big bang in particular. Yet its value is uncertain by about a factor two. The primary aim of the CHASE experiment was to improve dramatically the precision of our knowledge of the helium abundance. In addition the extreme ultra-violet telescope and spectrometer employed for this purpose were capable of measuring the abundances of several other elements (for example, iron, oxygen and sulphur) in the solar corona together with the electron temperature and density in coronal structures. The latter measurements permit a deeper understanding of the nature of coronal structures and how they are formed.

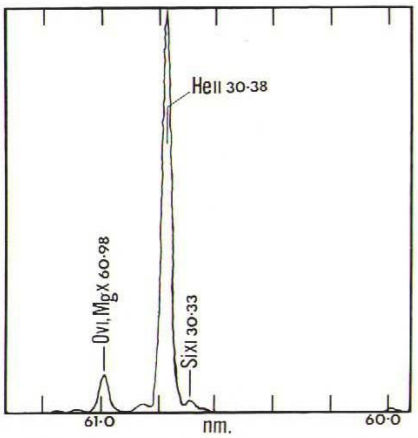
Since most of the helium in the Universe at present must have been produced at the time of the big bang, a current determination of this quantity in the atmosphere of a normal star should provide a cosmologically significant result. While the Sun offers a reliable site for abundance determinations in general, the situation regarding helium is complicated by the fact that hydrogen and helium emission lines are mainly formed in the chromosphere or transition region. This is the complex zone that exists between the relatively low temperature photosphere ($T \sim 5700$ K) and the thin high temperature ($T \sim 10^6$ K) gas that exists in the corona. The complex structures and the steep temperature gradient of the chromosphere make reliable abundance estimates impossible. However it is fortunate that emission in the prominent hydrogen and helium lines from the corona is due mainly to resonance scattering of the intense chromospheric emission in these lines. By looking at the prominent emission lines of hydrogen and helium from both the primary light source on the solar disc and from the scattering region in the corona, it is possible to measure the helium abundance with a precision of better than ±10%. In particular, when the line intensity ratio is calculated, several uncertain terms cancel out to first order and a relatively reliable expression which depends mainly on the helium abundance results. In addition, since both the source and the scattering region are being viewed by the same instrument, the final result is independent of the relative instrument calibration at the two chosen emission line wavelengths.

The emission lines employed are the well know Lyman -∝ line of hydrogen at a wavelength of 121.6 nm and the resonance line of singly ionised helium of 30.4nm. In the CHASE instrument used to register these lines, a grazing incidence reflecting telescope of 28 cm focal length focuses the solar radiation on to a movable entrance slit. Radiation from the slit is incident on a 1200 line per mm diffraction grating also used at grazing incidence. Light dispersed by the grating is registered on an array of single channel electron multipliers and on a channel multiplier array plate. By moving both the slit plate and the telescope, it is possible to collect radiation from anywhere on the solar disc or in the corona. Light from more than a dozen lines can be registered by the spectrometer in addition to the hydrogen and helium emission lines. Measurement of these line intensities allows the other aims of the experiment to be achieved. Line intensities are recorded by counting the number of detected photons per second in each of the channel multiplier detectors and transmitting the result to the ground. The whole instrument is controlled by a sophisticated microprocessor system which contains stored programs that allow a large number of different observing sequences to be executed.

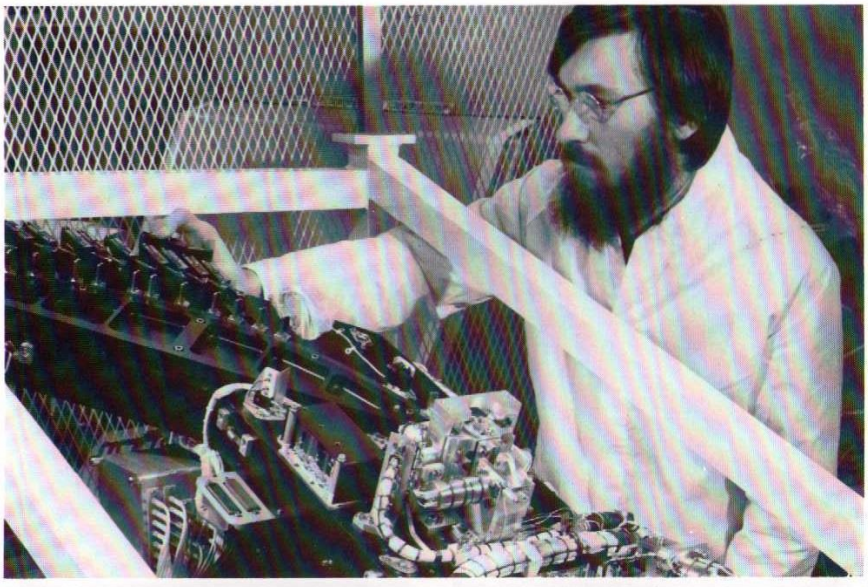
The instrument was launched on the NASA Spacelab 2 mission on July 29, 1985. Due to the premature shut down of one of the Space Shuttle's three main engines, the eventual orbit achieved was 315 km above the earth's surface rather than the planned figure of 380 km. Luckily the atmospheric absorption of the helium 30.4 nm radiation was much less than expected because of low overall solar activity and so the primary aim of the experiment should not be significantly degraded. The instrument performed faultlessly throughout the eight days of the mission and a large number of excellent spectra were obtained. A detailed analysis of the line intensities measured both on the solar disc and in the corona should yield the hoped for improvement in calculating the helium abundance together with a wealth of information on temperature and density of the tenuous hot gas that is contained in the large magnetic field structures that control the nature and appearance of the solar corona.

After the Shuttle's return to Earth, the spectrometer was returned to the UK to be checked, fitted with improved photon detectors and flown again by NASA in November 1987. It is of immense value to be able to continue observing the structure of the solar corona at a different stage of the solar cycle with a flight-proven instrument the properties of which are now well understood. In addition the further observing opportunity can be made available to the UK solar physics community at large.

Professor J L Culhane
Mullard Space Science Laboratory
Dr A H Gabriel
Rutherford Appleton Laboratory



A sample spectrum of the He emission.



The CHASE instruments undergoing final assembly before launch as part of the US Space Shuttle's Spacelab 2 payload in July 1985.

Commissioning the prime focus of the Isaac Newton Telescope

Although the Isaac Newton Telescope (INT) has been in routine use for almost two years on La Palma, until recently all observing has been done at the Cassegrain focus. This means that spectroscopy has been possible but not direct imaging. One of the main reasons why La Palma was chosen for the new observatory is that it has excellent 'seeing' conditions; stellar images are relatively undisturbed by the atmosphere above the site and remain small and sharp. This fact is important for spectroscopy but it is even more vital for imaging and so, although it was sensible to commission the more heavily used spectroscopic instruments first, the time came to incorporate the prime focus and enable the imaging potential of the site to be realised.

In July 1985 therefore a commissioning team went out from the Royal Greenwich Observatory to La Palma to undertake this task. The job had many aspects: optical alignment of the corrector assembly which gives the prime focus its wide field; commissioning of the autoguider system; installation and testing of the charge-coupled device (CCD) camera and its associated filter wheel, and checking out the software which controls the whole system.

The CCD camera itself is similar to the one already in use on the spectrograph, except that its CCD is made by RCA rather than GEC. The RCA device has the advantage that it is thinned and back illuminated, and therefore sensitive to blue and even ultraviolet light. Its disadvantage of higher read-out noise is not important when imaging through broad band filters, because shot noise on the (dark) sky background becomes the dominant noise source in less than two minutes exposure time. However the GEC camera may be of interest to some observers for doing short, narrow band exposures or where the better spatial resolution given by the smaller pixels (0.54 arcsec compared to 0.74 arcsec for the RCA) is required. Therefore some of the time was spent using the GEC system, and the data obtained will allow a detailed comparison of the performance of the two CCDs.

The autoguider

After the inital telescope alignment, the first task was to get the autoguider going. The autoguider measures the position of a star (offset from the object being viewed by the CCD) with respect to a fixed reference point. It reports any positional errors to the telescope control computer which adjusts the drive rates accordingly. Although the open loop tracking of the telescope is good, this additional error feedback from the autoguider is necessary to give the $\simeq \pm 0.1$ arcsec accuracy which is required if the good seeing is not to be compromised. There is no television viewing capability at the prime focus, therefore no other means of guiding is available and so the autoguider is essential.

The autoguider only intercepts a small portion of the telescope beam and so is on X-Y slides to give sufficient field coverage to ensure that a guide star can be found. In addition to basic autoguider operation, there was the daunting task of sorting out the relative sense and orientation of three different coordinate systems, some of which can be rotated with respect to each other. This is not easy at 4 o'clock in the morning and not to be recommended to those of a nervous disposition.

The CCD camera had already been tested and optimised in the laboratory and after checking that installation on the telescope had not affected its performance (for example, great care has to be taken with earthing arrangements in this fairly noisy electrical environment) the tests were aimed at assessing its astronomical performance. This was both to check that it was operating as predicted, and to provide essential data for subsequent users when planning their observing programmes, such as magnitude limits and sky brightness. Standard photometric sequences were observed for this purpose and an example is shown in figure 1. The faintest star which can be seen in this 10 minute exposure in the V band is of magnitude $\simeq 24.8$, which is about 1/16th of the brightness of the dark sky background.

Flat fields

Other tasks included investigating flat fielding methods. Flat fields are calibration images of uniform intensity which are used to correct the small pixel-to-pixel gain variations which occur in CCDs. The problem is to find a source of uniform illumination which provides a good colour match to the night sky. Two possible methods are to use the dawn sky, or the inside of the dome illuminated by a tungsten lamp. The former gives better overall uniformity but even against the bright dawn sky several stars normally manage to find their way into the frame. Using the inside of the dome overcomes this problem but achieving overall uniform illumination can be difficult. The data are currently being assessed to decide which is the better method.

Although thinned CCDs have an enhanced blue sensitivity, the fact that they are illuminated from the reverse side can give

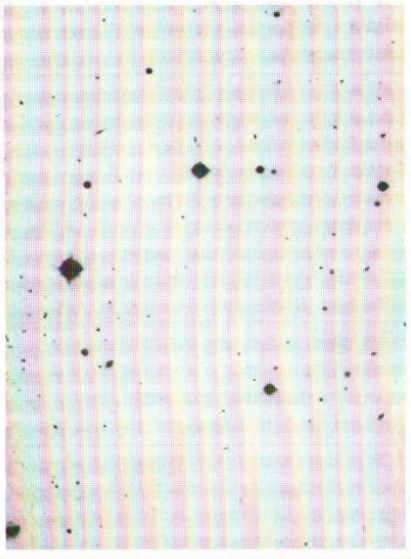


Figure 1: 10 minute V band exposure of the calibration field F1038-8

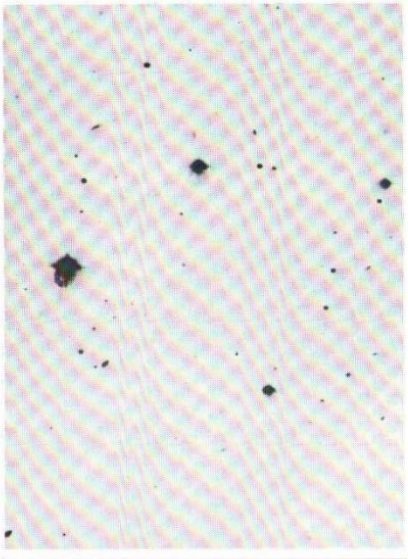


Figure 2: 10 minute I band exposure of F1038-8 showing interference fringes

rise to interference fringes in the narrow layers which make up the chip. These fringes are produced by night sky emission lines which are particularly prominent in the infrared bands. Their effect on an image can be seen in figure 2. Clearly the identification of faint objects and accurate measurements will be affected by their presence. Techniques have been developed at the RGO for their removal, but this is sometimes difficult and it is better if they are not there in the first place. It was therefore pleasing to see that in the R band, which is often the most useful band for deep exposures, there is little or no fringing. Figure 3 shows a deep 2000 sec R exposure on which no fringes can be seen. Their absence is due to a combination of factors: night sky emission tends to be low on La Palma; the R filter was constructed so as to avoid a particularly strong line; and this generation of RCA chips is less prone to fringing than some of the earlier ones.

The software

The software to control the system is important, and this is the aspect the user is most aware of. Procedures were devised to make observing as simple as possible. For example automatic focus exposures, automatic focus adjustment on filter changes, image width determination and exposure time calculation are among the facilities offered. The observer can display and manipulate (flat field, for example) and hence assess the data quickly and so adjust his programme, if necessary, at the telescope. Integration of the system has reached the point where the observer can select and acquire a guide star simply by placing a cursor on a suitable object seen on the finder field of the integrating TV system. This process is very quick and efficient and no advance preparation is necessary.

It is an unfortunate fact that the astronomical interest of a CCD image is often inversely proportional to its aesthetic appeal; figure 4 is included to show that CCDs can take pretty pictures when required.

In summary, there is now a first rate imaging facility on the INT which will enable observers to take full advantage of the good seeing and dark skies of the site.

Dr D J Thorne

Royal Greenwich Observatory

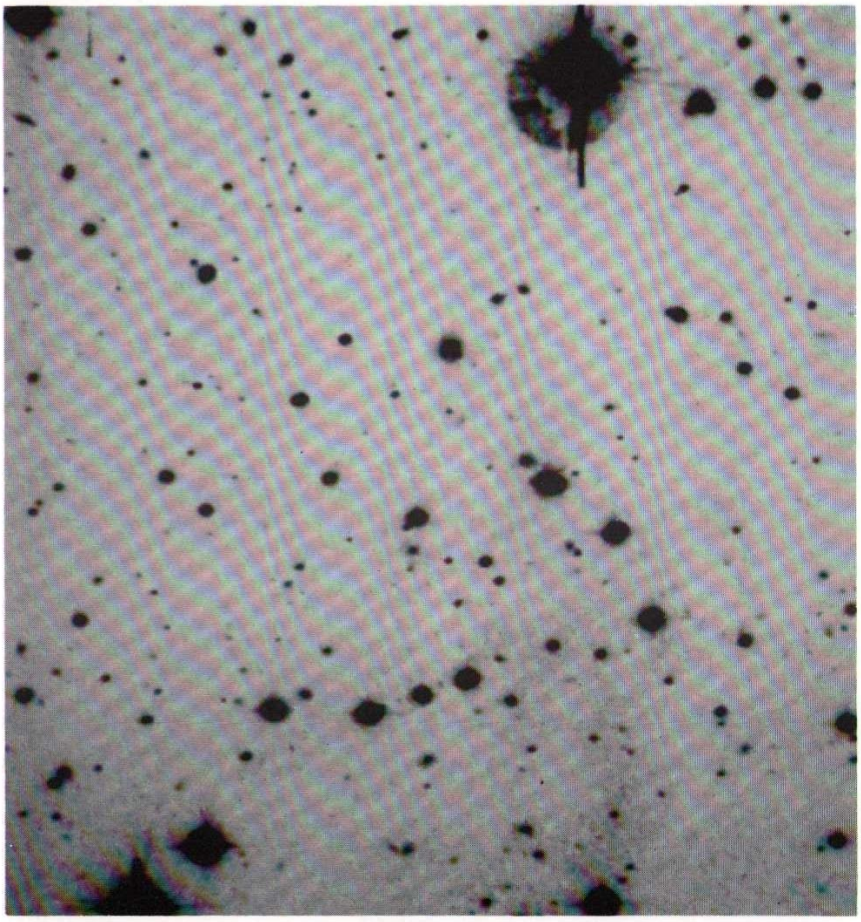
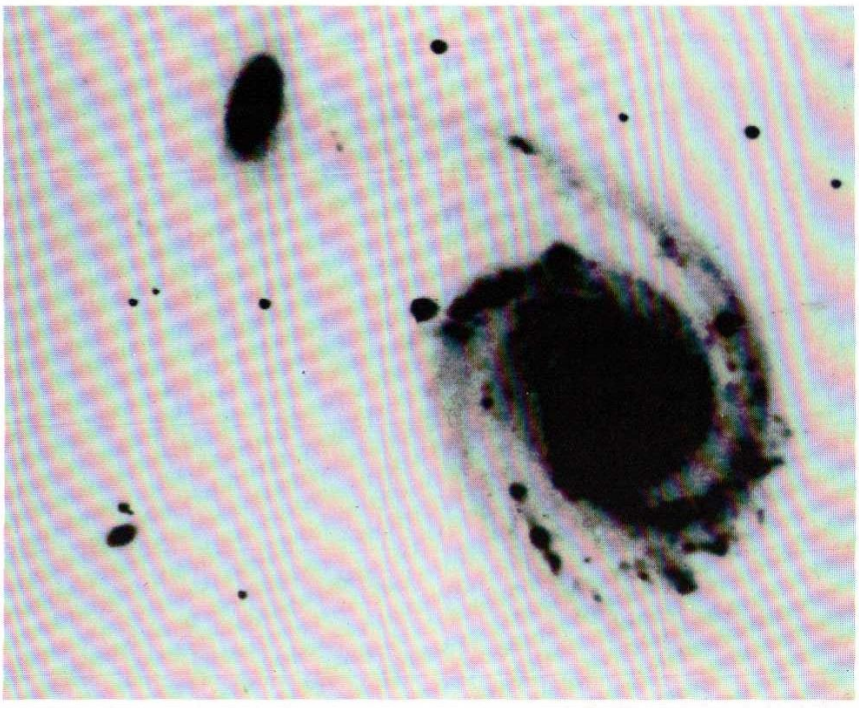


Figure 3: 2000 second R band exposure of 3C427.1 showing the lack of inteference fringes.

Figure 4: A pair of interacting galaxies, NGC 7753 (600 second, B band)



Hawaii — new headquarters, new instrumentation

SERC activity on the Big Island of Hawaii takes place at three levels — above, in and below the clouds. At sea level, the island has acquired an interesting new building and, at the summit, a new common-user photometer is providing astronomers with a much improved service.

Below the clouds

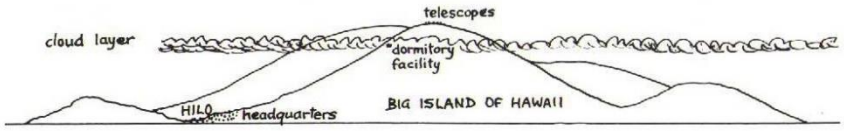
Down at sea level, in the town of Hilo, which is the administrative centre of the island, cloudy skies are normal and rain is very frequent - warm rain! The staff of the Royal Observatory, Edinburgh, who are responsible for the operation of the UK telescopes in Hawaii, have worked there for more than seven years in a converted warehouse where the lack of space and other adverse features of the office accommodation made life difficult.

In planning a custom-built headquarters in Hilo, the Council Works Unit has had to combine the requirements of the astronomers and the suggestions of a local firm of architects, Oda-McCarty Architects Ltd, into a cost-effective building. The ground-breaking ceremony (a typically Hawaiian event) was held on 23 July 1984 and the dedication ceremony, marking the completion of the first phase of the structure, was held on 9 August 1985.

The impressive roof of the new building (designed to deal efficiently with all that warm rain) is visible from many places in Hilo. It is a reminder to the local population of SERC's commitment to astronomical observation in the optical, infrared and millimetre wavebands from Mauna Kea, an extinct volcano which is rapidly becoming the world's best equipped astronomical observatory.

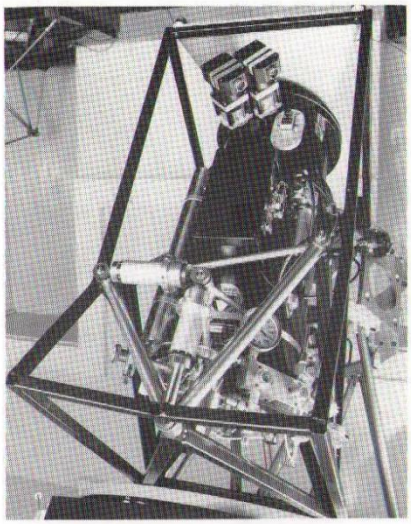
In the clouds

Half way up to the summit, at the 2800 metres level, there is a dormitory facility, called Hale Pohaku, where visiting astronomers and the support staff who work with them can recover from the rigours of work at high altitude. In this part of the world there is usually a temperature inversion layer which acts as a 'lid' for the dust particles and water vapour that come up from the surface. A layer of cloud frequently forms immediately below the inversion and as often as not it runs like a feather boa round the mountain at the Hale Pohaku level.



Above the clouds

At the summit, which rises to 4200 metres above the Pacific Ocean, is the Mauna Kea Observatory, a multinational enterprise with a growing cluster of telescopes. The UK Infrared Telescope (UKIRT), designed for work in the spectral range from 1 μm to 1 mm (although it has occasionally been used for observations outside that range), was opened there in 1979. It is operated by a dozen members of the ROE staff, assisted by locally engaged staff. Now being assembled a few hundred metres away by a team from the Rutherford Appleton Laboratory is the recently named James Clerk Maxwell Telescope (JCMT). This millimetre-wave telescope is a joint project of the UK and the Netherlands; it is to be opened in 1987. The JCMT is designed to be most efficient at wavelengths in the range from 500 μm to 5 mm, but with appropriate instruments it may well be used outside that range. The ROE will be responsible for its operation and development. Dotted around the summit are three other major telescopes and the foundation works for two more are in progress.



UKT14, a common-user continuum photometer for the UK Infrared Telescope in Hawaii.

New photometer for telescopes in Hawaii

The study of objects in space began with observations in the visible waveband but the invention of detectors for use at other wavelengths has enormously extended the scope of observational astronomy. Of particular interest at the present time is the infrared/millimetre-wave region of the electromagnetic spectrum.

Work at submillimetre and millimetre wavelengths is difficult because of the absorption of extra-terrestrial radiation by water molecules in the Earth's atmosphere but there are transmission 'windows' which can be used for ground-based observation from high, dry sites, such as Mauna Kea Observatory.

Common-user photometer

The telescopes are of course only as effective as their detectors. There is a suite of common-user instruments for use by visiting astronomical groups from universities and colleges in Britain, the Netherlands and elsewhere. The latest such device is UKT14, a continuum photometer designed to exploit the atmospheric transmission windows in the region from 350 μm to 2 mm. This instrument has been built at the ROE, in collaboration with Queen Mary College, London, and the University of Oregon.

Low temperatures

The new photometer employs a bolometer cooled to 0.35 K as the sensing element. Operation at this very low temperature is necessary to reduce the detector noise to around the level of the fluctuations in the signal from the sky at wavelengths of around 1 mm. The cooling is achieved by use of liquid nitrogen and liquid helium. To get down to so close to absolute zero there is a special closed-cycle refrigerator using the helium-3 isotope which can be pumped to a lower temperature than the normal helium-4 isotope. The University of Oregon has been responsible for the

design and manufacture of this device.

Very careful design of the optical and mechanical parts was necessary to minimise heat leaks, microphonics and detection of unwanted background radiation. For this project the ROE Laboratory Workshop had to embark on new types of work: machining lenses out of polyethylene and manufacturing highly polished stainless steel mandrels used to grow copper horns of parabolic form by an electrolytic process.

Filters

The effective wavelengths of the observations are controlled by a set of metal grid filters mounted in a wheel, the filter and the aperture for an observation being selected remotely. The primary wavelengths covered are 350 μm, 450 μm, 800 μm, 1.1 mm and 2 mm. These filters and the bolometers have been manufactured by the Physics Department at Queen Mary College, London. The filters have a passband, $\triangle$f/f, which can be varied from 1/3 to about 1/20.

Sources

When the sky is viewed through broadband filters at submillimetre and millimetre wavelengths the main feature observed is thermal emission from dust at temperatures of around 50 K to 500 K in molecular clouds in our own galaxy and in other 'star burst' galaxies. This thermal emission from dust is believed to be caused by embedded young stars. Mapping such regions at submillimetre wavelengths will lead to a better understanding of the complex processes which bring about the birth of stars. Emission from heated dust is also observed in late-type stars which are undergoing mass loss. Other objects which produce measurable radiation fluxes at these wavelengths are quasars and Seyfert galaxies where the emission is thought to be produced by synchrotron processes. Millimetre and submillimetre measurements are combined with measurements at other wavelengths to derive constraints for the models of such processes. Some of the sources are observed to vary with time and the rates of variation give limits for the physical dimensions of these objects. Also being studied at these wavelengths are the Sun, the planets and the asteroids in our own solar system.

Expectations

This new photometer should prove to be an important tool for the investigation of these phenomena with the greatest possible sensitivity. Telescope commissioning tests begin on the UKIRT in January 1986, with the first observations scheduled for February. The instrument is optimised for use on the UKIRT but it is planned to use it for the commissioning of the JCMT during 1986. With the larger telescope (the JCMT has an aperture of 15 m compared with 3.8 m for the UKIRT) there will be an improvement of ten times in sensitivity and of four in spatial resolution. Astronomers are fully expecting to make significant discoveries with the new photometer.

Dr Bill Duncan and Bennet McInnes
Royal Observatory, Edinburgh

Prizewinners visit ROE

'The Comet is coming!' was the headline given in *New Scientist* to an essay competition sponsored by SERC, the British Association Young Scientists and *New Scientist*. The comet in question is of course Halley's and the competition, which was open to 13 to 20 year olds, was to write either on observing it with the facilities available today, or on some aspect of the history of its appearances.

The first prize was a visit to Kourou in French Guiana for the launch of Giotto, the European Space Agency's satellite which will intercept Halley's Comet, skimming past its nucleus in March 1986.

Other prizes included a visit to one of the two Royal Observatories. Five prizewinners, aged 16 and 17, visited the Royal Observatory, Edinburgh, for a day in August 1985, three boys from Edinburgh, Birmingham and London, and two girls from Manchester.

'Comets in history' was the theme of the first item on their programme as they got the opportunity to see (and to handle!) books and manuscripts in the Crawford Collection. This library contains first editions of nearly every book important in the history of astronomy and related fields, some of the material dating back to the thirteenth century.

One highly successful part of the visit was to the Plate Library of the UK Schmidt Telescope where the visitors could themselves study deep space photographs obtained with this telescope, and pick out stars, galaxies and comets. A presentation pack of photographs of comets taken with the Schmidt telescope was given to each prizewinner.

The Astronomer Royal for Scotland entertained them to lunch and then their programme continued with talks and exhibits about the use of the COMOS machine, to measure the position of the comet accurately (so that the satellites heading for it are kept on track), and the UK Comet Halley watch. They saw the pass of a weather satellite on equipment in one of the laboratories of Edinburgh University's Astronomy Department and learned something of the astronomy courses that the Department runs with assistance from Observatory staff.

Dr Jocelyn Bell-Burnell
Royal Observatory, Edinburgh

Dr Russell Cannon, Deputy Director of the Royal Observatory, Edinburgh and Head of the UK Schmidt Telescope Unit, shows astronomical photographs to the winners of the Halley's Comet competition.

Antennas to medicine — Microwave diagnostic imaging

Microwave holographic imaging began by mimicking optical holography. With the introduction of digital computing and graphics facilities, it has now evolved into an electromagnetic measurement and data processing philosophy which is experiencing wide interest in antenna and dielectric measurements, electromagnetic scattering and inverse methods. Work at Sheffield University, which emphasises the measurement and recovery of complex field data, and their inversion to the scattering sources or their transformation to other spatial regions, is yielding new applications of microwave diagnostic imaging.

Over the past five years we have seen microwave metrology accepted as the preferred technique for the evaluation of reflector antennas, and near-field to far-field transformation techniques established throughout microwave antenna engineering. The application of complex field processing to dielectric materials, including the ground sub-surface and living tissue, is offering attractive results and challenging theoretical problems. Diffraction tomography is now the subject of intense study and, in the microwave regime, offers solutions to the problems of determining internal parameters, with important medical aspects relating to microwave hyperthermia for the treatment of malignant disease. The wider interest in inverse methods is leading to new techniques for determining the vital phase data from intensity-only measurements which will supplement traditional holographic-based data recording.

The past five years have also seen a substantial growth in microwave diagnostic research in the Department of Electronic and Electrical Engineering at Sheffield University, supported by an SERC grant for microwave and millimetre wave antennas, image diagnostics and digital image processing.

Volumetric antenna metrology

Microwave holographic metrology of reflector antennas is being extended to provide a full volumetric diagnostic capability applicable to all antenna types. Figure 1 shows some results of half-space recording and data inversion from the Ewald sphere. Figure 1(a) demonstrates the phase reconstruction capability for two surface aberrations on an unblocked reflector selected in the plane containing the left-side error. The process quantitatively sifts the antenna volume providing the maximum possible resolution which is unattainable by conventional microwave holography. This technique also provides array element excitation measurement as indicated in figure 1(b). The amplitude image of a slotted waveguide array has been obtained from measurements of orthogonal far-field components and represents one equivalent current density component of the slot current.

Intensity-only measurements

The development of techniques for determining phase values from non-holographic intensity-only measurements is illustrated in figure 2. As applied to a reflector antenna, (a) shows the conventional microwave holographic result for the aperture phase and (b) shows the result obtained after retrieving the phase data from intensity-only

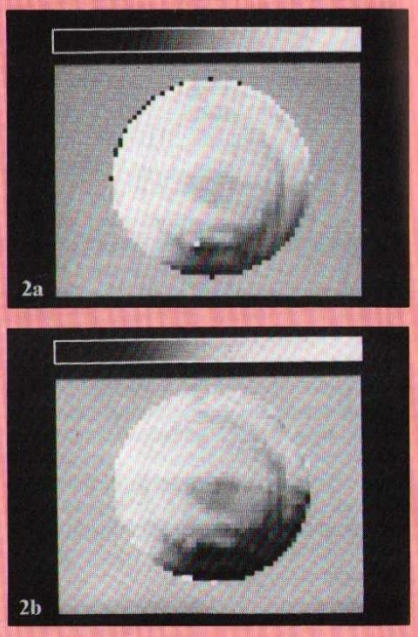
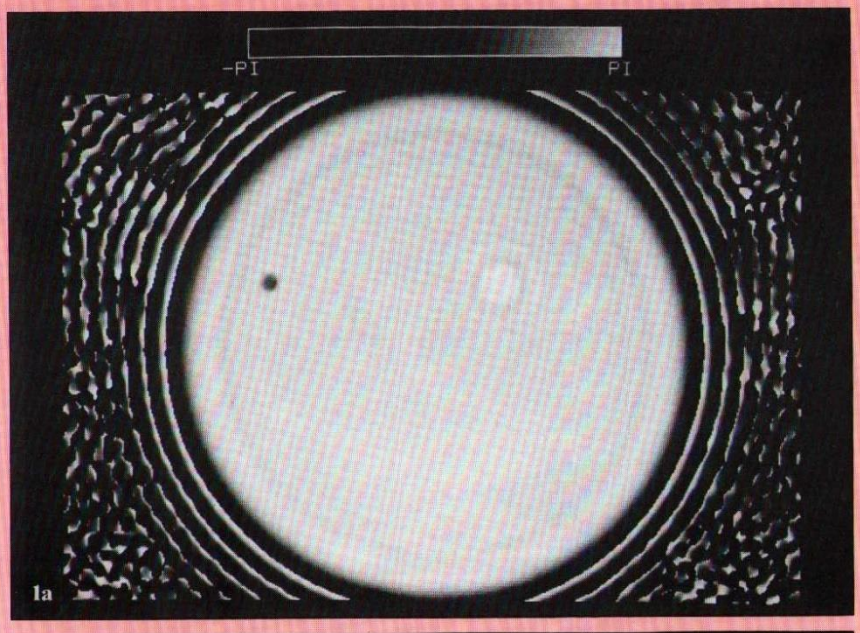


Figure 2 : Comparison of 120λ microwave reflector aperture phase measurements:
(a) Holographic measurement
(b) Phase retrieval from intensity measurements.
Grey level scale represents phase change from -180 degrees (black) to +180 degrees (white).



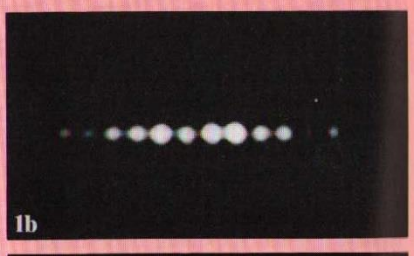


Figure 1 : Volumetric antenna metrology
(a) Phase image of 32λ diameter reflector with two small deformations focused on the left-side perturbation.
(b) Amplitude image of a 12-element slotted waveguide array with slot spacing 0.9λ .

measurements of the radiated field requiring no reference channel nor physical access to the antenna.

Diffraction tomographic imaging

The three dimensional diagnostic capability of microwave holography is limited by wavelength but is substantially improved by diffraction tomographic imaging. The inverse techniques required for reconstituting images from multiview and multifrequency data are now receiving widespread consideration for both microwaves and ultrasound. Because of diffraction problems not encountered in X-ray computerised tomography, many challenges remain in the generation of suitable image reconstruction algorithms. The continuing progress in this quest is illustrated by figure 3 which shows the potential of phase tomography to determine internal dielectric parameters from scattered fields.

Field Prediction Methods

The modelling of electromagnetic imaging problems is a vital aspect of this research and considerable effort is being expended in field prediction methods. Figure 4 shows an example of a spectral domain technique for which the computational algorithm is extremely efficient. The field values provided by this approach agree very closely with those from classical theory and hence provide confidence for application to arbitrary shapes for which there are no analytic solutions.

Phased array hyperthermia

The use of microwave radiation to heat tumours to clinically therapeutic temperatures is provoking many challenging electromagnetic studies to achieve and control the required power deposition within the body. Phased array hyperthermia offers the possibility of selective deep heating of malignant tissue. The design of suitable antenna systems requires predictions of radiation into heterogeneous or layered tissue structure. Figure 5 shows the expected result for a fat-muscle-lung heating path indicating the need for phased multi-applicator radiation sources to achieve sufficient heating in lung tissue without excessive doses elsewhere.

In addition to the dedicated laboratory and computer graphics facilities in Sheffield, the Microwave Group also operates an extensive, automated field site near Buxton, Derbyshire. Scanning systems for data acquisition within a 15 m x 6 m anechoic chamber or over several ranges up to 1.5 km are controlled from the console shown in figure 6.

A P Anderson

Professor of Electronic and Electrical Engineering
Sheffield University

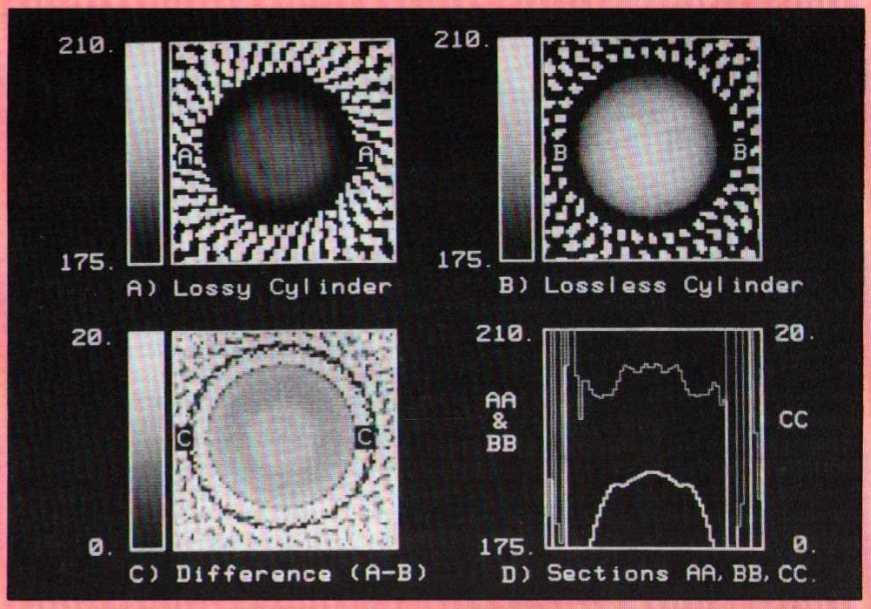


Figure 3 : Phase tomographic reconstruction of a composite dielectric cylinder of outer radius 5λ . Exact and reconstructed values of dielectric loss in each region show close agreement.

Figure 4 : Forward and reverse scattered fields from a conducting cylinder of 3λ radius. The efficiency of the incremental diffraction algorithm makes it attractive for bodies of arbitrary size and shape.

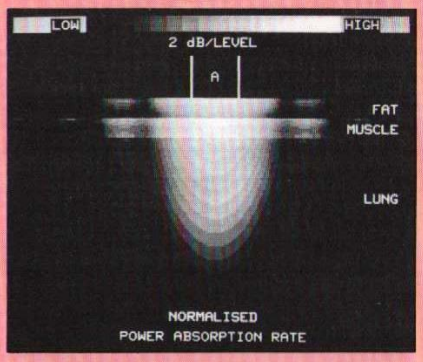


Figure 5 : Power deposition of a waveguide applicator in contact with fat-muscle-lung media. The prediction is used in the design of a phased-array hyperthermia system.

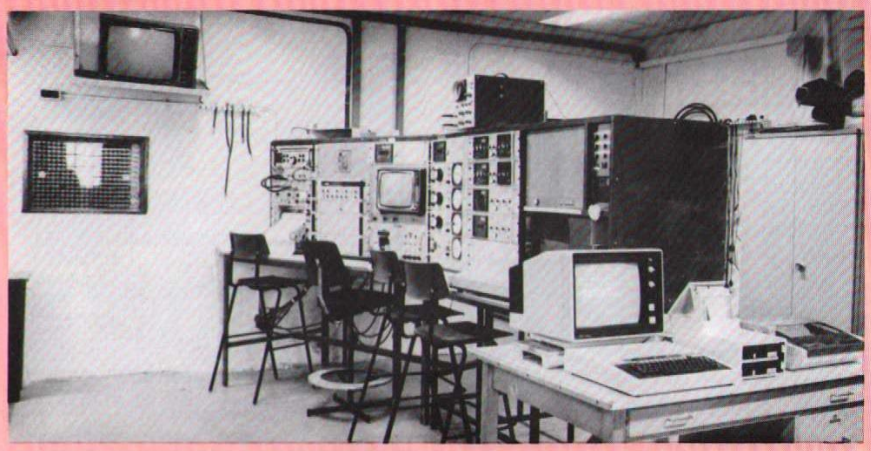


Figure 6 : The control console at the Buxton field site showing the receivers, positioner controls, synchro/digital converters and data logger. The anechoic chamber is just visible through the observation hatch to the left.

Variable-shape electron beam lithography

Electron beam lithography (EBL) has been recognised as the principal means of fabricating high definition masks for microelectronics, but it is essentially too slow to be a viable manufacturing method for direct writing on semiconductors because it is a serial writing process. The challenge of producing a viable high-throughput technique without compromising the flexibility of pattern generation available from electron beams has been overcome with a variable-shape lithography system, CUMMS IV, developed at Cambridge University. This is capable of producing a gain in writing speed of 100 times or more over conventional lithography systems, while achieving submicron line-widths with edge resolution as fine as 70 nm. The research could form the basis of a future generation of high speed and high resolution EBL systems for the direct fabrication of very large scale integrated circuits with submicron dimensions.

Electron beam lithography came into its own in the 1970s because of its promise as a very high resolution fabrication technique for making the patterns required in very large-scale integrated circuits. As the practical use of the technique developed it soon became apparent that the throughput was very limited and certainly insufficient for the needs of the semiconductor chip-making industry which is geared around mass-production methods.

Among the many schemes put forward to increase the speed of electron beam lithography was the concept of variable-shape writing. A conventional EBL process is shown in figure 1(a): three rectangular areas are produced with a round beam which has a Gaussian current distribution, the beam is focused to about one quarter of the minimum shape to be written, so that edge definition is maintained in a serial writing sequence used to fill in the shape. The step-by-step nature of this process makes it slow. In the alternative scheme, proposed in the mid-70s, the beam is formed into any desired shape which is printed in just one flash on to the substrate as illustrated in figure 1(b). The shape and its position are both controlled by a computer system which stores the pattern data for the circuit. The rate of information transfer is therefore greatly increased with little loss in the flexibility obtained by computer control of the writing process.

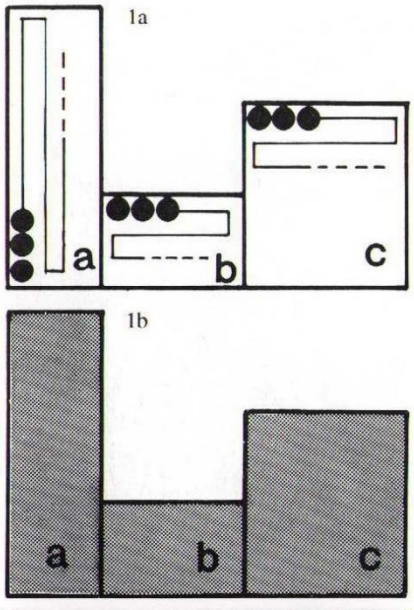


Figure 1(a) Conventional electron beam writing strategy. (b) Single flash exposure of each rectangular shape.

Research was started six years ago with an SERC rolling grant to determine whether or not these concepts could be realised; these are the results achieved.

Computer modelling of the variable-shape high-current electron beam column

An important aspect of the research programme was to develop a computer-based simulation of the optical performance of the column. At the beginning of the research, the existing means for the analysis of electron beams were not suitable, because the high currents used in a variable shape caused the beam to suffer from electron interaction effects and trajectory displacements in addition to the more usual chromatic, spherical and deflexion aberrations in conventional EBL systems.

A Monte Carlo modelling technique was chosen and a suite of programs was developed to model high-current shaped beams. These gave information needed for rapidly optimising the design parameters before undertaking the time-consuming and expensive design and construction stages of the components of the electron column and its control systems.

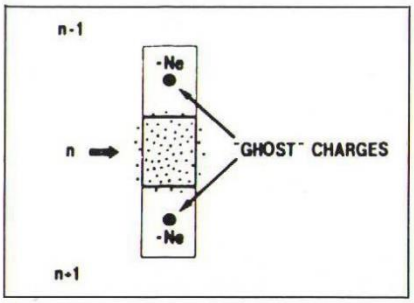


Figure 2. Simulation of the high current beam as an electron packet with ghost charges.

In this model the electron beam is first formed in a cross-over at the electron gun with its energy-spread parameters. The beam is modelled by breaking it into packets which travel through the length of the column. The trajectories of all the electrons within a single packet are evaluated, and the effect of the rest of the beam on them is simulated by the use of ghost charges introduced on each end of the packet. As the packet travels in the column the position, velocity and acceleration components of the electrons are determined as a result of both electron-electron interaction and the influence of electron-optical elements such as lenses, shaping components and deflectors. The

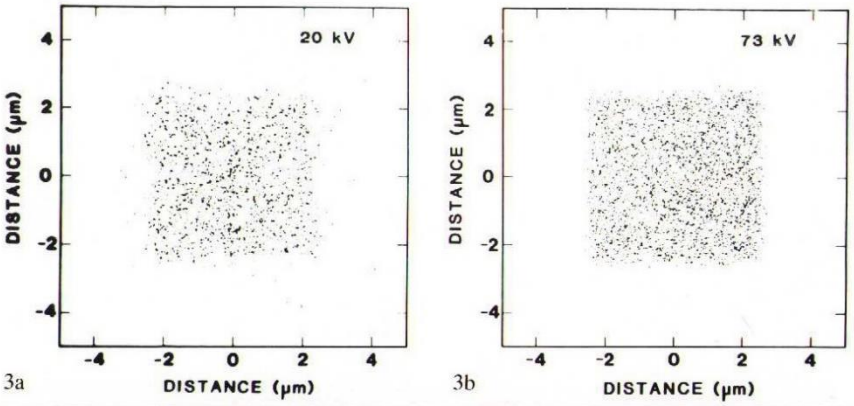


Figure 3. Image of 5 μm square at: (a) 20 kV beam energy and 100 times demagnification, (b) 73 kV beam energy, 100 times demagnification.

packet is stepped along the column and the equations of motion are re-calculated at each step. Trajectory displacements cause some electrons to fall outside apertures and these are eliminated, while the remainder are formed into the final image. A typical pattern predicted by the program for a sample number of electrons forming a shape of 5 μm × 5 μm nominal size is shown in figure 3 for a typical operating condition of 20 kV beam voltage and compared with the pattern predicted at a higher voltage. These types of results enabled the correct choice of optical conditions, and operating voltage was raised to 100 kV to take advantage of the higher resolution available at high current densities.

The variable-shape EBL system, CUMMS IV

The essential elements of a variable-shape electron beam lithography column are an electron gun capable of producing uniform and stable illumination of a beam-defining aperture; shaping optics in which a very fast means for changing the beam shape and some demagnification of the beam is included; further demagnifying lenses to form the minimum linewidth required in the circuit pattern; and a deflexion system to write over a given field-size on the substrate. In addition to these elements, high resolution alignment and correction coils must be incorporated in the system. To complete a fully operational machine, the electron column must be combined with a suitable mechanical stage, and both electronic and computer control systems. Figure 4 shows the electron beam system developed during the course of the research. It contains all the significant elements of a very high speed writing system and only lacks system-integration with operational software to make it a prototype for a commercially viable machine. The gun operates at voltages up to 100 kV and can use either a tungsten or an LaB_6 emitter. The beam-shaping apertures are anisotropically etched squares in silicon made at the Edinburgh University Microfabrication Facility. Electrostatic deflexion is used to change the shape at high speed. Typically the operating conditions use a beam current of about 3 μA and a beam current density of greater than 20 A/cm^2 in a basic shape of 3 μm × 3 μm. A total demagnification of around 100 times is used and a field of 1 mm × 1 mm may be exposed by post-lens deflexion coils without stage movement. The gain in speed of such a system compared with a conventional system is dependent on the pattern details, but in most cases can be expected to be 100 times faster. There is a very little loss of flexibility in pattern generation compared with a conventional EBL machine with a round beam and a Gaussian current distribution in the focused spot.

Results, conclusions and future prospects

The high resolution and aspect ratio obtainable are clearly demonstrated in the examples illustrated. The study has shown conclusively that high-throughput electron beam lithography can be realised with 0·1 μm resolution. The Rutherford Appleton Laboratory has now undertaken a project funded by the Alvey Directorate in collaboration with industry, to help the university research team to transfer its designs, information and prototypes to industry and to seek the commercial exploitation of the project. It remains to be seen how effectively this objective will be realised in the next few years.

H Ahmed and G A C Jones
Microelectronics Group,
Cavendish Laboratory,
Cambridge University

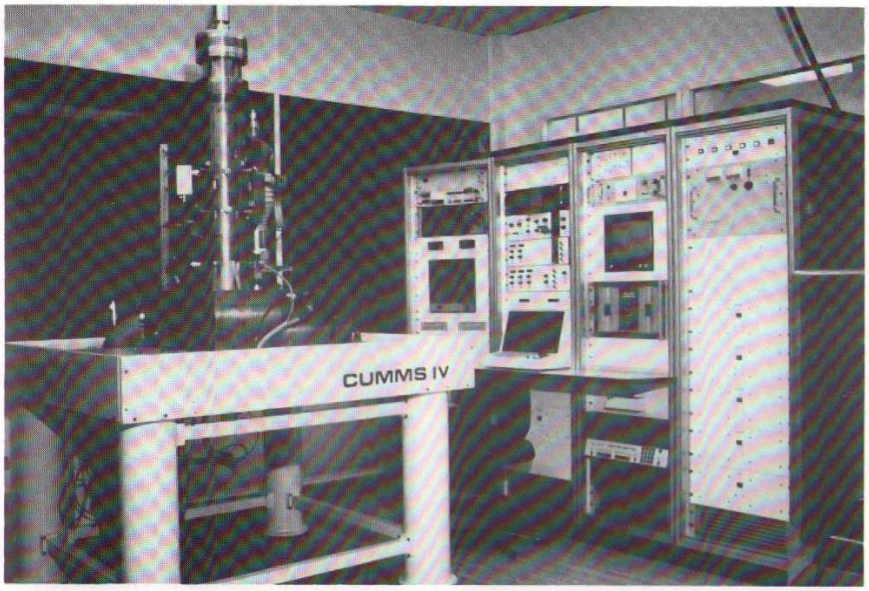


Figure 4. Cambridge University variable-shape electron beam writing system (CUMMS IV).

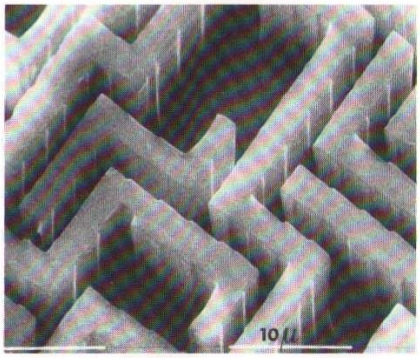


Figure 5. Part of a circuit pattern formed in 6 μm thick electron resist. The small irregularities along the sides are caused by butting of the shapes.

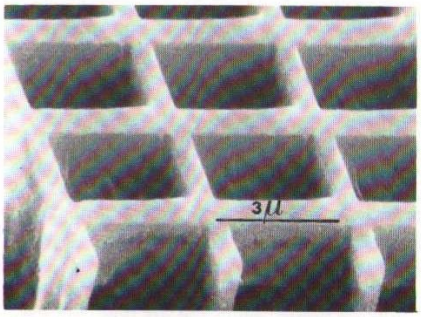


Figure 6. Grid pattern with submicron walls in a 2·5 μm thick resist.

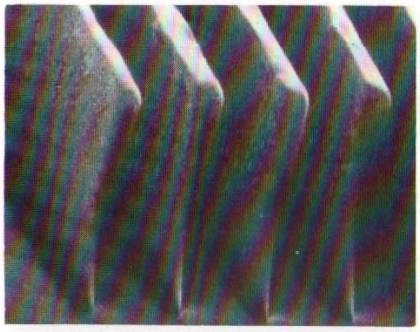


Figure 7. Part of a grating pattern with 0·2 μm thick strips.

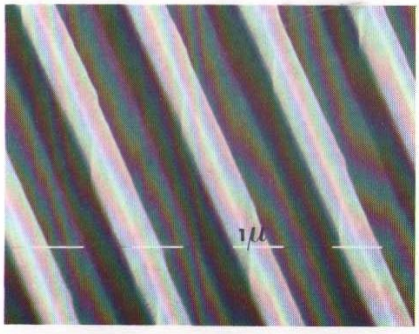


Figure 8. Submicron, high aspect lines of resist covered with a 0·2 μm gold layer. (Micrographs: T S Norris)

Computing convective heat transfer in buildings

A thermo-fluids research team at Cranfield has received an award for developing improved means of calculating convective heat transfer data.

It is estimated that building services account for more than 40% of primary energy consumption in the UK. The need for the efficient use of energy in buildings is therefore obviously important, particularly when viewed against a background of depleting North Sea oil and gas reserves. In order to develop realistic methods for the energy-conscious design of buildings, it is necessary to simulate the dynamic thermal response of the system. One of the main tasks of the Specially Promoted Programme on Energy in Buildings has consequently been to encourage research in this area (see *SERC Bulletin*, Volume 3 No 2, June 1985). However, a weakness in all the modern approaches to building thermal modelling is that emphasis has been placed on simulating the transient performance of the building fabric, while the air flow and convective heat exchange in and around the structure are modelled using only rough approximations. Indeed, a comprehensive study of the new generation of building thermal models, by the International Energy Agency in the early 1980s, concluded that their accuracy is presently limited by uncertainties in the input data, particularly for air infiltration and convective heat transfer data.

In order to obtain improved convective heat transfer data for building thermal models, the Energy in Buildings programme sponsored the development at the Cranfield Institute of Technology of a hierarchy of interacting and inter-dependent calculation methods over the period 1980-85. The work was undertaken by a small team of thermo-fluid dynamicists in the School of Mechanical Engineering, led by the author. The calculation methods were initially developed for warm-air heated and mechanically ventilated enclosures, such as domestic rooms or commercial offices. They ranged from 'lower-level' approaches, including analytical solutions and elaborate data correlations for limiting cases, to the development of a 'high-level' flow model that solves the governing 'elliptic' equations for the complex, jet-induced room airflow. The latter model uses 'finite volume' approximations of the partial differential equations for a three-dimensional computational grid. It has been incorporated into a computer program called the ESCEAT (*E*lliptic Equation *S*olver for *C*onvection and H*e*a*t* *T*ransfer) code, and is based on the solution methods developed by Professor D B Spalding FRS and his co-workers at Imperial College of Science and Technology during the 1970s. Both the higher and lower-level models have been used to develop and verify an intermediate-level computer code, known as the ROOM-CHT (Room Convective Heat Transfer) program. This code has been used to generate input convective heat transfer data for dynamic building models. Typical results obtained with the model for the complex heat flow pattern over one wall of a warm-air heated room are shown in figure 1.

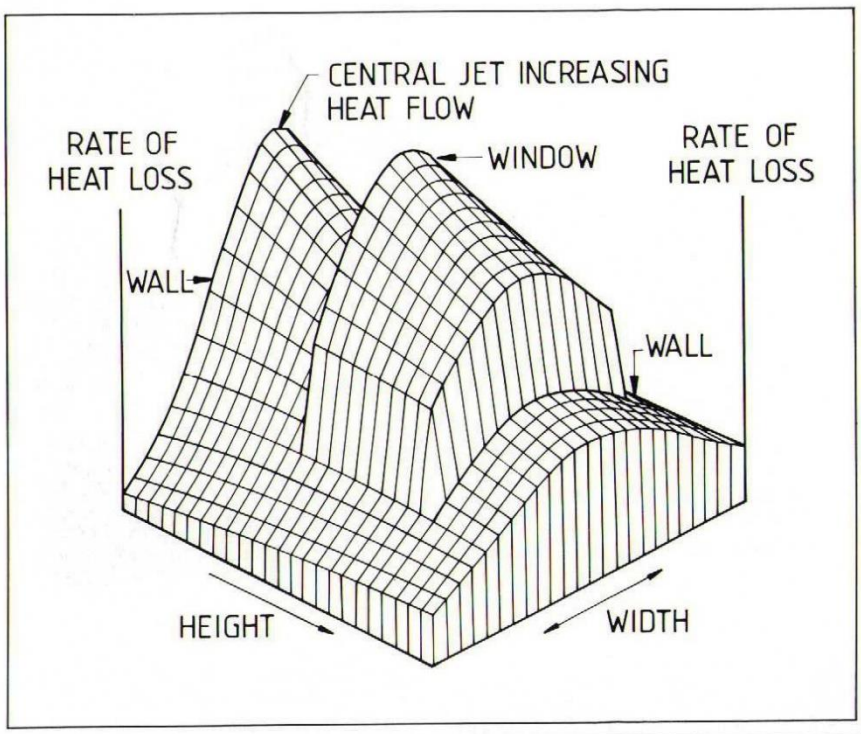


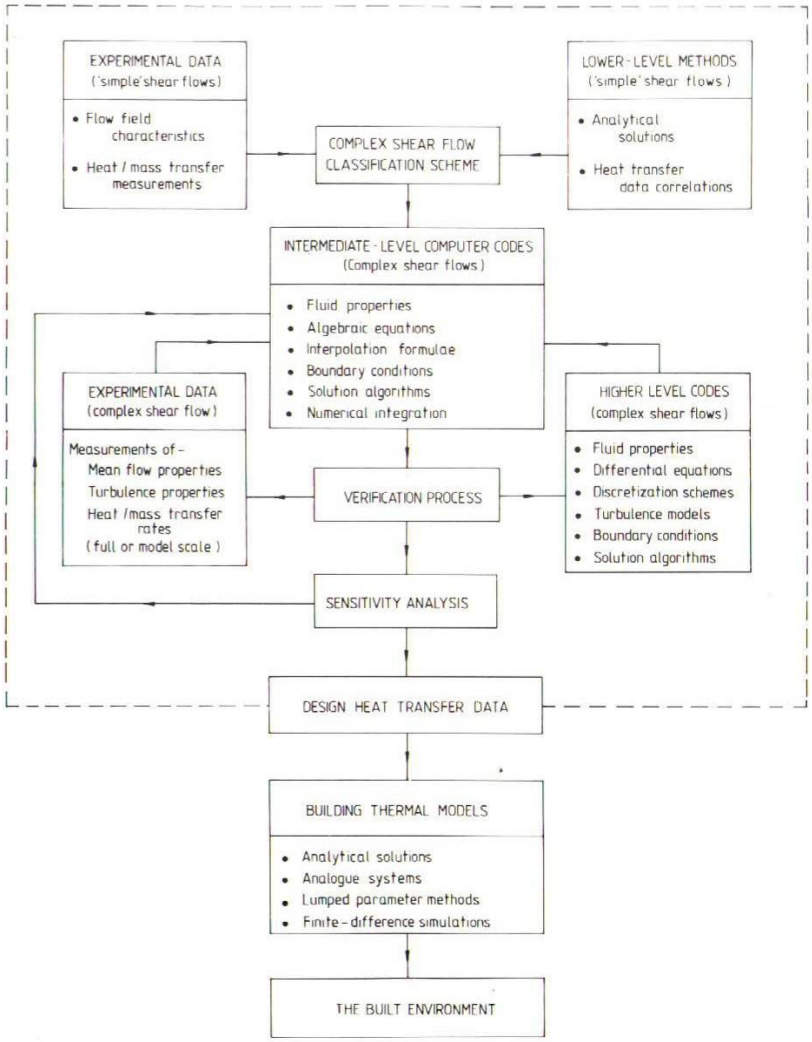
Figure 1. Heat loss variation as a central, heated jet of air passes over the internal surfaces of an exterior wall and window (computed by the ROOM-CHT program).

Economy and user-friendliness

The success of the above approach led the Cranfield team to develop in separate, but related, studies two further intermediate-level sub-system models: one for building external convection and the other for multi-zone air-infiltration. The way in which calculation methods of this type evolve is illustrated by the schematic diagram shown in figure 2. The blocks within the dashed line represent the iterative process of developing and verifying such methods. Scale-model mass transfer measurements have been used at Cranfield for validation purposes. Local heat/mass transfer data have been obtained from the sublimation of naphthalene on the surface of a test rig used to model certain critical elements, such as supply apertures and window recesses. It has been found that, although higher-level methods are better able to simulate complex flow patterns, they are often less accurate than intermediate-level methods in computing surface heat exchange. This is due to limitations in the current 'turbulence models' used in the former. Nevertheless, the main benefits of intermediate-level computer codes for convective heat transfer are their economy and relative user-friendliness. The commercial exploitation of all the air flow and convection software developed at Cranfield has recently been assured by a provisional agreement with Amazon Energy Limited of Milton Keynes.

Despite the fact that the main research effort by the Cranfield team has been directed towards the problem of so-called

Figure 2. Development sequence of intermediate-level computer programs for building convective heat transfer.



'forced' convection, they have also considered buoyancy-driven convection in rooms. Their interest in this rather different phenomenon was stimulated by a discussion with Dr J A Clarke of ABACUS, Strathclyde University, at one of the Energy in Buildings community-wide meetings. The author and Dr F Alamdari, who have been with the project from its beginning, agreed to try to produce a set of correlating equations which would reduce the risk of numerical instability in the sophisticated building thermal simulation program, ESP, developed at Strathclyde. This was achieved by adopting more elaborate expressions which were presented in a convenient form for incorporating into modern building thermal models. They also displayed better agreement with recent experimental data than do the 'standard' equations recommended in the various design guides. The results of this research were published in one of the research journals of the Chartered Institution of Building Services Engineers (CIBSE) in 1983, and the paper was awarded the Institution's Dufton Silver Medal earlier this year. The Medal is given to the authors whose paper contributes substantially to scientific knowledge of a theoretical nature in the area of heating, ventilating and/or air conditioning.

The research by the Cranfield team has wider implications for the application of what is now called computational fluid dynamics (CFD). The building industry, in common with many others, is comprised of relatively small- and medium-sized firms with minimum expertise in CFD. They are therefore unable to make direct use of complicated, higher-level finite-element or finite-volume CFD programs. Thus there is a need to provide an interface that would aid the transfer of the sort of design information obtained from CFD methods to such companies. The Cranfield approach of developing intermediate-level computer codes is one method of generating such an interface. Doubtless there are likely to be alternative approaches, but these developments will provide a challenge for the CFD research community in the universities for some time to come.

G P Hammond

Senior Lecturer in the Applied Energy Group, Cranfield Institute of Technology, and a member of SERC's Building Subcommittee.

Richard Tully, retiring President of the CIBSE, presenting the Dufton Medal to Farshad Alamdari (centre) and Geoff Hammond (right) at the Institution's 1985 AGM.

Partnership in success

The Teaching Company Scheme, which has been jointly funded over the last ten years by SERC and the Department of Trade and Industry, is now also supported by the Economic and Social Research Council and the Department of Economic Development (Northern Ireland). There are nearly 200 current Programmes; the budget of the Scheme is about £10 million, more than 35% of which is contributed by the participating companies themselves. Each Programme is a partnership between a company and a university or polytechnic. Here we highlight two of the Scheme's many success stories.

Birmingham Polytechnic with British Federal Ltd

The Programme is a partnership between British Federal Limited, part of the Laird Group, and Birmingham Polytechnic's Electronic and Electrical Engineering Department. The team at the polytechnic is coordinated by Director of Research Dr A M Higginson and Head of Faculty Dr F Arthur. Coordinators for the company are Managing Director John Birch and Technical Director John Stanway.

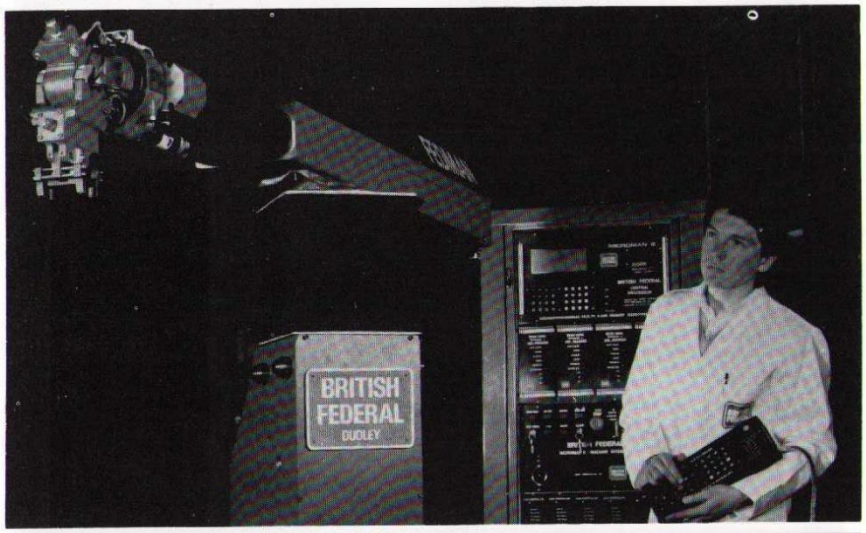
The Programme started in 1982, following a feasibility study into multi-axis robot control undertaken for British Federal by Dr Higginson. By 1984 the Programme team had developed a wide range of welding machines employing microprocessors, microcomputers and programmable logic controllers. It had also designed a central monitoring system for robot lines and sophisticated hand-held programming controls for welding equipment, as well as being actively interested in the development of centralised control of groups of robots within a total manufacturing system.

By this time two more Associates had been added to the original team. The main aims were twofold. First, to develop and implement a universal programmable logic control program which would be able to cope with the increasingly high degree of sophistication and complexity demanded by the customer of the future. Second, to enhance new high technology testing methods in line with the envisaged future demands in relation to production standards and greater feedback of detailed information.

The Microman 8 microprocessor-based control system is the main development project area to be covered by the work of the Programme team. The Microman 8 control system is designed to provide accurate simultaneous control of up to eight DC servo motors and also provides the user with 24 inputs and 24 outputs for machine sequence control. It is particularly suited to a total flexible systems approach.

The control system of the Microman 8 is modular, which allows easy servicing as well as high reliability, and is designed essentially to control robot movements. One great advantage of a modular control system is that it is easy to expand and can therefore cater for specific user requirements. For example, from an eight axis control system it can be built up to control as many as 15 axes.

A 32 key menu-driven key-pad, above which there is a large eight line by 40 character liquid crystal display, is used to program the control system. Alternatively, a hand-held remote teach pendant can be employed. The key-pad is also a means of data entry and function control using simple English statements, to enable easy programming. Communication links through an RS232 interface to a printer enable direct program print-outs. Also using a RS232 interface, data may be loaded on to magnetic tape. Once the data is on tape it can be stored using a large (1 million bits) bubble memory facility. Microman 8 has been developed to provide reliable control of robots under harsh industrial environments.



The Microman 8 microprocessor-based robot control system: a controller working with a typical robot (Photo: British Federal Ltd).

The Ford Motor Company was quick to appreciate the Microman 8 controller and in the last quarter of 1984 placed a £2 million order with British Federal for 45 robot welders and controllers for two plants. The success of the project has prompted an extension of the Programme to support further development of the Microman 8 through design and manufacture of a 'second generation' universal programmable controller. This will offer more computer power and also a greater degree of flexibility.

Briefly, the extended Programme has two parallel objectives. First, the present Microman 8 system will undergo a complete review. Technical developments will include :

- modularisation
- monitoring present performance and investigating a new drive system
- implementation of coarse moves
- software routines for incremental moves and mirror images
- critical appraisal of the performance of resolvers and their interfacing
- design and building of a serial programmer including display and key-pad
- appraisal of various types of display including gas plasma

Second, the new controller itself is to be designed and built, including :

- new central processor unit based upon 16-bit architecture to offer more computing power
- implementation of a much faster system bus protocol
- generation of software for interpolation of various kinds
- intelligent input/output processor with a high speed scan rate to communicate with the central processor
- provision of a visual facility

Microman 8 is already being successfully applied in the manufacture of automobile floor pans, chassis, roof and side lines at the Ford Motor Company. When the further development work of the Programme has taken place the UK will have a universal controller with world-wide sales appeal.

Aston University with Kimbell Construction Ltd

Aimed at streamlining site management procedures by creating computer support for existing site methods, this Programme was originally set up in December 1983 between Kimbell Construction Ltd of Northampton and Aston University's Department of Civil Engineering and Construction. Kimbell Construction Ltd operates in the East Midlands, East Anglia, the South of England and the London area. Its annual turnover is more than £8 million and it engages in roadworks, main drainage and building construction, most of its work being for public authorities. Contracts range in size from £2,000 to £75,000.

The construction industry has particular and traditional management problems, such as spread of sites and unsuitability for 'routinisation' of management decisions. This has led to heavy reliance on a company's site managers and estimators as well as long established working practices. The two-year Programme set out to improve analysis and forward planning of on-site operations, improve cost control, create refinements in the evaluation of future contracts and develop an adequate database.

Application of computers

The Department of Civil Engineering and Construction at Aston has been very active for some time in the application of computers in construction management. It has a computer applications research group led by Dr Ken Mulholland, working on operational estimating, cash flow forecasting and site management problems. An economics group was established some time ago under senior lecturer Alasdair Traill, with responsiblity for developing the teaching of economics in the department and initiating research in construction micro-economics.

This group had been working with local industry and government on the problems of inner city land use, and contact between Kimbells and Aston University was established as a result of this work. The Programme was established under the supervision of Alasdair Traill at Aston, with a Director of Kimbells, Douglas Gibbs, as main representative for the company.

Objectives

There are basically four objectives for the Programme:

- To identify those decisions taken by site agents that combine a high risk of failure with a high resultant penalty.
- To provide computer support for site management. This requires the provision of both hardware and software. In particular, the planning techniques in use in the construction industry lag far behind those developed by recent operations research. In part, this is due to the suspicion by the industry that any mathematical representation of what is seen as an unusually complex productive process will be simplistic and unhelpful. In fact the opposite may be true; many modern techniques are over-detailed for an industry that is not familiar with the maintenance of a database and has a very high degree of flexibility within the ordering of operations. The purpose of the Programme is therefore:
- To adapt existing methods to the point where they become viable.
- To initiate the collection of the information that will be required to service the incorporation of more advanced techniques over the next decade.
- To ensure that sufficient numbers of Kimbells staff are trained to use the system created and to expand it following the end of the Programme.

Achievement of these objectives as part of the process of incorporating computer-aided management techniques can be viewed under the broad general headings of technique, data and training.

Technique

The core of the planning model and the cost and valuation model are in operation on selected sites. Software has been written rather than purchased for reasons of cost and in order to provide editing flexibility throughout the next phase. These packages permit date storage and retrieval within the bill of quantities, as well as the provision of interim costs and valuations. Currently, planning statements are expressed solely in terms of time; resources are included in a rudimentary form and no cost statement can yet be made. If a site agent is to be able to investigate the consequences of alternative strategies, he must be given both functions. Costing is being introduced by integrating the two existing programs. Resource evaluation was completed at the end of 1985. This will enable the central office to plan at the company rather than the site level. It will also provide the basis for assessing inventory policy and determining the most efficient stock levels.

What if ...?

No comparison of alternatives will be fully effective without the inclusion of probabilistic outcomes. At present, the 'what if' problem has been the subject of advanced and unused or untested techniques. The Programme must work towards the incorporation of such techniques into the solution of pratical problems. Realistically this will not happen before the end of the Programme, but solutions to several of the difficulties involved are expected.

In addition, certain preliminary work has been requested by the company's head office management that initially aims at improved estimating, but which could eventually lead to the emergence of improved bidding strategies. This has been completed and is in operation. Communication is being established between the microprocessor at head office and those on site. Intercommunication between sites is also likely.

Data

Every project within the Programme relies heavily upon data. Currently, emphasis is being placed upon the provision of techniques for which information is short-lived and readily available. Certain techniques, however, such as probabalistic planning and bidding theory, require lengthy series of data where collection must be started well in advance. This project must predict changes in technique that may occur within the next decade and advise on the collection and storage of the required information.

Training

Throughout the Programme two microprocessors have been available on site. At least two site agents must be able to operate the system; they should be in a position to use the techniques available, edit the existing system in order to incorporate special features and have sufficient knowledge of management techniques to advise on and control the evolution of the system beyond 1986. For company personnel not directly involved, a basic understanding of computer systems is essential.

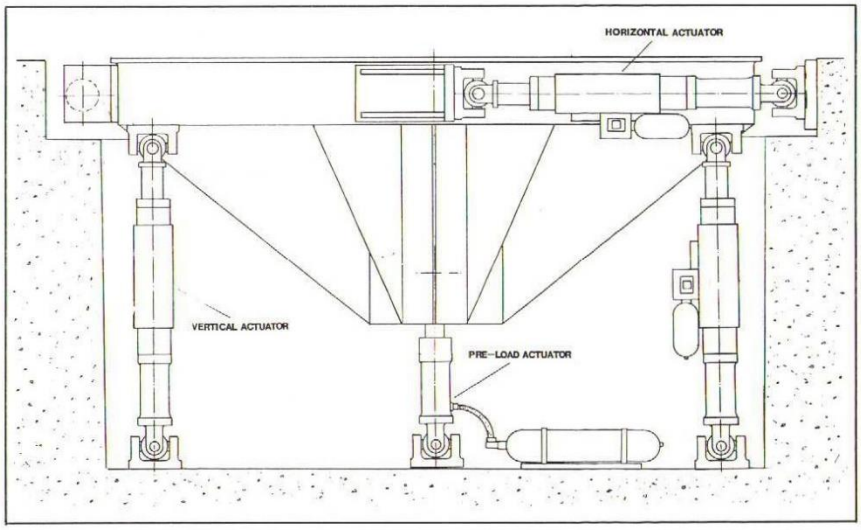
Valuable contribution

Kimbells has already indicated that the Teaching Company has exceeded its expectations now that the real potential of the operation can be seen. There is no doubt that senior management is convinced of the value of the university's contribution. They have indicated a strong desire to maintain the links once the Programme has finished. The university view is that the Teaching Company Programme has provided a good foundation for a long-term relationship with the company. Theoretical work at the university is being test-run and modified on the company test bed.

Dr D P Jones
Teaching Company Scheme

Earthquake simulator at Bristol

The recent earthquake in Mexico has highlighted the difficulties faced by civil engineers in ensuring that hospitals, dams, bridges and other structures can survive the effects of severe earthquake shaking. Although the British Isles do not experience earthquakes of the magnitude of the Mexico event, it is still essential for UK engineers to be competent in earthquake engineering if they are to be successful in a highly competitive overseas market. As part of the earthquake engineering research programme being undertaken with SERC support, a large earthquake simulator, or shaking table, is being constructed at Bristol University at a cost of £473,000. The simulator will enable large models to be shaken by recorded earthquakes and other motions.



Bristol's six-axis platform — side view.

The simulator, which will be constructed by Silveridge Technology Ltd of Slough, will consist of a 3 m by 3 m cast aluminium platform capable of carrying a maximum payload of 15 tonnes. The platform will be capable of controlled motion in six axes (two horizontal, vertical, pitch, roll and yaw) and will be driven by eight servo-hydraulic actuators, four acting vertically at the corners and four acting horizontally. A ninth actuator will support the dead weight of the platform and test specimen. The actuators will be rated to produce 1.0 g acceleration simultaneously in all three translational degrees of freedom for a 5 tonne payload. Operating frequency range will be from approximately 0.5 Hz to 100 Hz. The platform and actuators will be mounted in a 100 tonne concrete reaction block which will be supported on air-spring vibration isolators and located in an existing pit in the laboratories of the Civil Engineering Department at Bristol.

Motion of the platform will be controlled by a minicomputer system using software provided by Principia Mechanica Ltd and existing software developed at Bristol. The platform will be able to reproduce earthquakes from actual earthquake records, spectrum compatible motions, sinusoids, sine sweeps, random noise, impulses etc. The computer system will include data acquisition from up to 64 channels and the associated data processing software will include a wide range of digital signal processing options and modal analysis. Access to the SERC and Joint Academic computer networks will be provided.

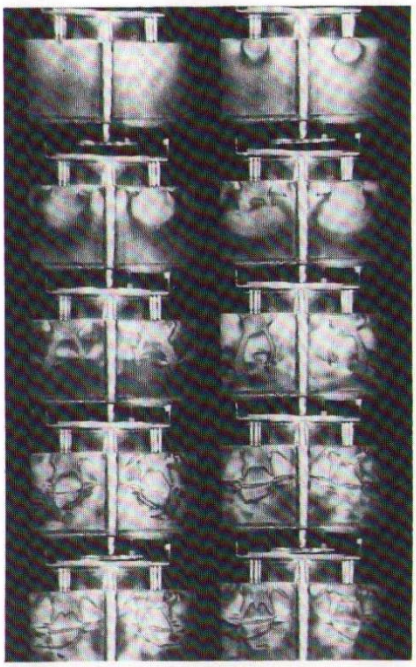
Construction of the facility has started and it is planned to have the simulator operational by the end of 1986. It will be available to SERC-supported users as part of the earthquake engineering research programme. Following an SERC research seminar held in November 1984 at the Institution of Civil Engineers, a considerable number of projects requiring the use of a shaking table have been proposed. These include structure/foundation response of buildings, bridges and guyed masts, torsional stability of framed structures in earthquakes, performance of infilled panels and energy absorbing mechanisms, and the seismic response of dam structures. Over the next twelve months, the Structures Steering Group and the programme coordinator, Professor Roy Severn, will be preparing a programme of research projects utilising the simulator.

When the simulator is complete, UK earthquake engineers will have ready access to a research-oriented facility on a par with those available in the USA, Japan, Italy and West Germany. This should provide further stimulus in an increasingly important branch of civil engineering.

High speed camera

Through its Process Engineering Committee, SERC has recently purchased an Imacon 790 high speed image converter camera system. This uses an image tube in which the electron beam, generated by the optical image on a photocathode, is chopped, deflected and shifted electronically, thus enabling it to reach 20,000,000 frames a second. Plug-in modules allow the framing rate to be adjusted down to 10,000 frames a second. Normally eight frames can be taken per event, but up to 20 are available. A particular advantage of the camera is that a normal photographic flash unit provides sufficient lighting. The system, which is held and maintained at Rutherford Appleton Laboratory, is readily portable and can quickly be set up on site at institutions.

Interested SERC grant holders, who believe that the camera could enhance their research, are invited to contact:
Technical matters: Mr P Goodyear, RAL, telephone Abingdon (0235) 21900, ext 6272.
Administrative matters: Miss K Booth, SERC Central Office, Swindon, ext 2484.



Crack propagation in a rock sample, recorded at 100,000 frames a second by the Imacon 790 high speed converter camera system.

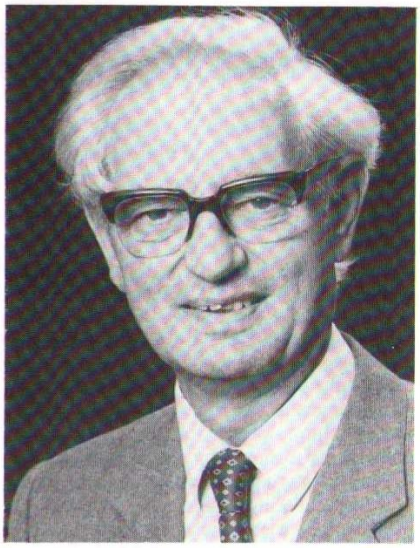
Engineering design coordinator

After the endorsement by the Engineering Board and the Council of the Lickley Report on Engineering Design (*SERC Bulletin* Vol 3 No 2, June 1985), SERC last year placed a contract with the Design Council to implement the report's recommendations. SERC and the Design Council then jointly appointed **Professor Joseph Black CBE, FEng** as the Engineering Design Coordinator.

Professor Black, who took up his new appointment on 1 October 1985, worked in aerodynamic research at RAE Farnborough and aircraft design at de Havilland Aircraft, then lectured on aeronautical engineering at Bristol University until being appointed Head of the School of Engineering at Bristol College of Science and Technology in 1960. He was a founder member of Bath University, of which he was Pro-Vice Chancellor 1970-75. He pioneered the teaching of Engineering Design in a highly innovative engineering course, the success of which has led to him travelling extensively in the US, Canada, India and Hong Kong in an advisory capacity, particularly on the introduction of CAD/CAM. He served on the Universities Grants Committee from 1964-74, many SERC committees and working parties, and on the Requirements Board for Mechanical Engineering of the Department of Trade and Industry. He was elected to the Fellowship of Engineering in 1980, and has served on its Council.

Professor Black will advise SERC on grant applications as well as advance and develop the Engineering Board's policies and initiatives in engineering design. His activities will be overseen by the Board's Management Committee on Engineering Design, chaired by Professor Michael French of the University of Lancaster.

Other members of the Management Committee are K Grant, Director of the Design Council; G E P Constable, Head of its Industrial Division; J Barnwell, Vice President, Bechtel Great Britain Ltd; Professor L Finkelstein, City University; Dr D A Melford, Director of Research, TI Group; Sir Alan Muir Wood, Sir William Halcrow and Partners; and Dr R G P Voss, Head of Engineering Division, SERC.



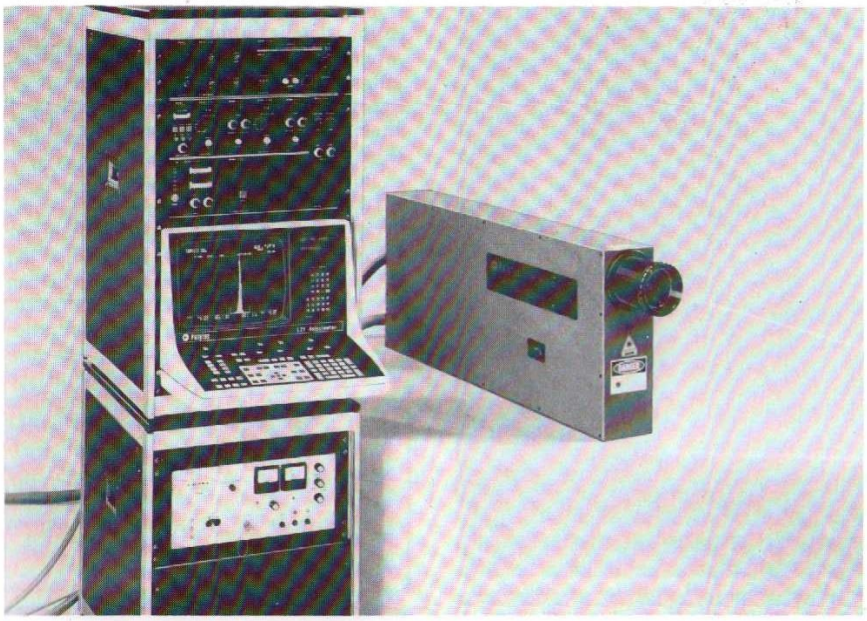
Professor Joseph Black CBE, FEng

Professor Black is based at the Design Council, Haymarket, London (telephone 01-639 8000) and is looking forward to talking to universities and polytechnics who wish to become involved in this initiative.

Laser velocimeter

SERC's Machines and Power Committee has bought a Polytec L2F-4000 laser velocimeter for use by investigators needing to measure the high speed gas flows met in rotating machinery like internal combustion engines, gas turbines, etc.

The instrument uses the Lexel Model 85-1 Argon Ion laser with prism wavelength selector, which has been shown to be very suitable for this application, and the measurement principle is based on the two-spot method of laser anemometry. This involves splitting a laser beam to form two very small, adjacent spots of light within the machinery being measured. Tiny particles of matter suspended in the gas stream pass through the spots in succession, giving two pulses of light. The time interval between these pulses gives the gas velocity, the flow angle being capable of measurement at the same time. Velocities can be determined over a range from 0.5 m/sec to more than 3,000 m/sec.



The Polytec L2F-4000 laser velocimeter

The equipment comprises a complete Polytec L2F system, including the laser measuring head, control electronics, a multichannel analyser for storing and displaying measurement results, and a microcomputer for data reduction. It has been decided to extend the data handling/presentation facilities by adding more memory and a colour graphics display. The equipment, which is to be held and maintained at the Rutherford Appleton Laboratory, is easily transportable and readily set up on site.

Holders of relevant SERC grants, who believe that the velocimeter could materially aid their research, are invited to contact:

Technical enquiries: G E Gallagher Daggitt, RAL, telephone Abingdon (0235) 21900, ext 6266.

Administration: Mrs E Vanderwalt, SERC Central Office, Swindon, ext 2200.

Developments in fatigue testing facilities

Sheffield University's Mechanical Engineering Department is developing advanced testing techniques on their newly built test facility

Recent aircraft accidents have led to an increase in public awareness of the dangers of metal fatigue; and yet more lives are lost each year from metal failures of more common structures including automobiles, motor-bikes and even bicycles. Potentially more dangerous are the cyclic forces generated in a nuclear plant which can be induced for example by thermal shock cycles and it was the apparent inadequacies of the engineering design rules used by the nuclear industries which provided the impetus for studies into metal fatigue failure under complex stress cycles. As in most fundamental engineering research, it took only a short time for these studies to be seen as relevant for components in other industries, such as railway lines which suffer a rotating principal stress field, or turbine rotors which suffer rotational bending superimposed on transverse shear and torsional oscillations.

In the early 1970s, research in the UK clearly indicated that a single parameter, such as the equivalent tensile stress generated in a body by the application of several externally applied forces, could not adequately correlate fatigue failures from different loading systems. Instead, two parameters were essential and it was proposed that they should be the parameters that defined the largest strain circle created in a fatigue cycle and the position of that strain circle in strain space. From figure 1 it is clear that these two parameters, namely 0.5 ($\varepsilon_1 - \varepsilon_3$) or the maximum shear strain, and 0.5 ($\varepsilon_1 + \varepsilon_3$) the strain normal to the plane of maximum shear, could be controlled independently of each other, and experimental proof was produced to show that the classical formulations for fracture stresses (or strains, or strain energy) should not be used for evaluating the safety of a structure or component. It was also shown that despite the fact that the intermediate principal strain ε_2 does not appear in the calculation of the above two parameters,

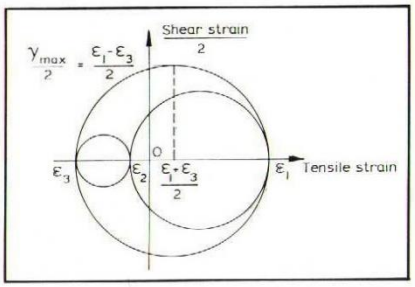


Figure 1: Mohr's circles of strain.

its orientation in relation to the orientation of the surface of the body is vitally important since this controls the type of crack which is initiated. If the direction of ε_2 is normal to the surface, then the crack grows in a direction parallel to the surface but, if ε_2 is parallel to the surface, the crack growth direction is away from the surface and penetrates into the bulk of the material; the latter case is obviously more dangerous.

Once these facts became established, safety-conscious UK industries required to know what effects the extent and degree of biaxial and multiaxial forces had on the integrity of their proposed and existing structures, and fatigue research into nuclear, aerospace, automobile, steam generation and railway materials increased. Doubts were soon to be expressed on the usefulness of the relatively simple uniaxial test that has generated much data for more than a century because, in this type of test, only one parameter is controlled (for example, ε_1) and the crack path is therefore pre-destined.

The unique facility, shown in figure 2, was built on a £210,000 SERC grant. It can now

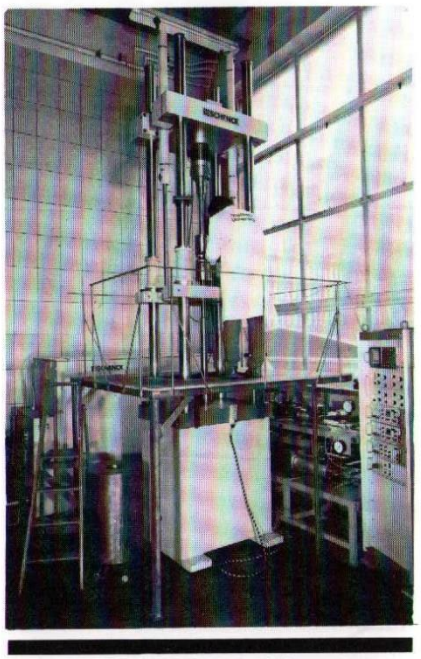


Figure 2: An overall view of the main loading frame, high pressure intensifier system, control panel and pressure vessel mono-block of Sheffield's multi-axial fatigue machine.

test materials for a specified strain state or any complex rotating strain state. Tubes can be subjected to clockwise and anticlockwise torsion, tension and compression, internal pressure and external pressure, in any desired combination. Cracks can therefore be generated on any plane orientation and can grow in any direction on that plane. For the first time the effects of rotating principal stresses can be evaluated by setting up the required sequence of the various loading modes on a computer, and tests controlled by a microprocessor. The effects of both material anisotropy and crack wedge pressures can also be quantified.

Coincident with these developments in the Mechanical Engineering Department at Sheffield University, UK industries are now setting up research programmes to study the effects of complex stress cycles on structural integrity, the EEC are supporting research through a BRITE joint industry-university programme, and new design codes of practice are being introduced. Figure 3 shows tests underway at the GKN laboratories where the fatigue strength of motor vehicle axles is determined via a loading pattern derived from road-test information which is fed independently into each one of several hydraulic jacks to produce twisting and bending forces that are similar to those experienced in service.

Further details on these and other developments can be obtained from the author at: Mechanical Engineering Department, Sheffield University, Mappin Street, Sheffield S1 3JD; telephone (0742) 78555 ext 5160.

K J Miller
Professor of Mechanical Engineering
Sheffield University

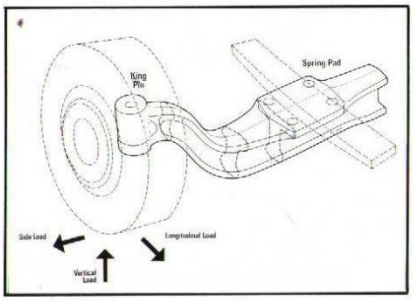


Figure 3: Fatigue strength of motor vehicle axles under test at the GKN laboratories.

Membrane separation processes

Although transport phenomena in membranes have been studied by biologists and chemists for more than 150 years, the industrial use of membranes in separation processes dates from the introduction of dialysis in the paper industry shortly before World War II. After the war desalination by electrodialysis began and over the succeeding 25 years steady progress was made in scientific and technological research that resulted in the development to commercial viability of a number of new membrane-mediated separation processes such as hyper-, ultra- and micro-filtration, pervaporation and membrane gas separations. Currently total sales world-wide of membranes and associated plant are believed to be in the region of about $2 billion annually, with growth over the next ten years expected to top 10% annually for existing processes. Intensive research is being carried out throughout the world, in both academic and industrial research laboratories, on improved membranes and new applications. This will result in the launching of new processes and in further improvements in those industries that incorporate membrane separations beneficially into their operations.

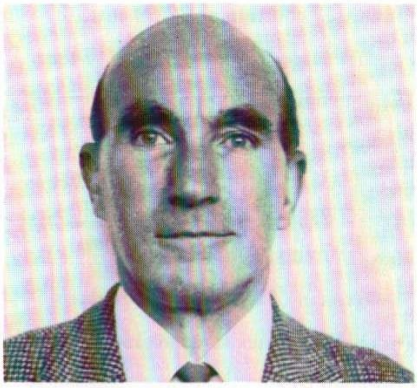
In view of the potential importance of the subject, five SERC Committees — Biological Sciences, Biotechnology, Chemistry, Materials and Process Engineering — agreed in Autumn 1984 to support a review of current UK academic and industrial research in this area aimed at identifying areas in which there may be merit in enhancing the UK academic research base. Professor Meares, of the Department of Chemical Engineering, Exeter University, was commissioned to carry out this study and his report* *Synthetic membranes and their applications* was submitted to SERC in May 1985.

The report showed that the UK as a whole had failed to participate fully in the development and application of the new membrane technologies. Thus the UK plays only a minor role as a membrane supplier, and process plant suppliers in the UK rely almost wholly on imported membranes and modules. UK companies that would benefit from the introduction of membrane plant into their manufacturing processes appeared to have grasped such opportunities on a considerably smaller scale than have their counterparts in USA, Japan and mainland Europe.

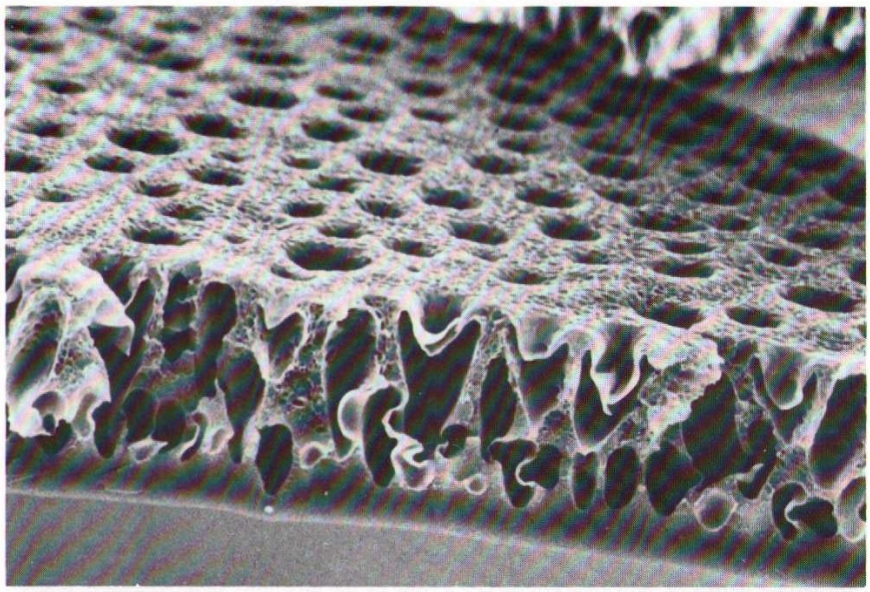
The report suggested that industry would be encouraged to look more favourably on the introduction of the new membrane technologies if there were an active group of researchers working in that area based in academic institutions in the UK. Although the survey revealed more than 20 persons scattered through the UK universities and polytechnics working in one way or another on membrane phenomena, in no case was there a planned and continuing programme on a range of membrane processes that could be described as a school of membrane science. Large areas of the subject were being scarcely touched upon whereas in other areas, particularly ultra-filtration of biopolymers, there existed several related but uncoordinated programmes that could benefit from improved inter-communication. Almost no basic research was being done on new or improved membranes, efforts being concentrated on extending the ways of using existing membranes. The general conclusion to emerge was that the level of fundamental research and training on membrane-related topics in the UK was lower than in other developed countries and that this appeared to contribute to the delay in the more widespread introduction of membrane processes into UK industry.

The report contained a number of recommendations aimed at encouraging academic multidisciplinary research and increasing the general awareness among the scientific and technical community of the current and developing potential of membrane processes. The five SERC committees who commissioned the report gave the recommendations their general support and Professor Meares was appointed coordinator for the period September 1985 to August 1986 to implement the recommendations for encouraging research and training. Furthermore the Process Engineering Committee and Biotechnology Directorate have agreed to earmark funds to enable the establishment of one or two significant multidisciplinary groups in the area. Researchers within universities and polytechnics considering seeking SERC support for activities in this area are advised to approach Professor Meares at the Department of Chemical Engineering, University of Exeter, Exeter EX4 4QF (telephone Exeter (0392) 263651).

Dr Doug Yarrow
SERC Biotechnology Directorate



Professor P Meares



An asymmetric membrane made from polymers derived from Victrex (polyether sulphone) (Photo: ICI plc)

**Copies of the report are available from Ms J Orme, Biotechnology Directorate, SERC Central Office, Swindon, ext 2310.*

Marine technology short courses

for March - December 1986

Title	Venue	Date
Non-destructive testing	Aberdeen	Mid March
Marine engineering geology	London	17-21 March
Oil and gas production systems	Aberdeen	24-28 March
Introduction to underwater video systems	Aberdeen	Easter
Remote sensing and image processing for applied geologists	London	Spring
Workshop on marine corrosion	Manchester	Spring
Materials and corrosion engineering	Aberdeen	April
Stress corrosion and corrosion fatigue of engineering structures	Newcastle	April
Wave action on maritime structures	Liverpool	7-11 April
Prestressed concrete and steel structures	London	14-16 April
Pressure surges in pipe and duct systems	Cranfield	15-17 April
Microbiology and oil production	London	17-18 April
Geology of petroleum	London	May
Designing to avoid failure in offshore engineering	Cranfield	12-15 May
Flow induced vibrations	Cranfield	12-15 May
Management of contracts and projects	Manchester	12-16 May
Turbine and vortex flowmeters	Cranfield	3-5 June
Inspection techniques for the future	Cranfield	3-5 June
Geophysical signal processing	Strathclyde	June-July
Offshore materials engineering	Aberdeen	30 June-4 July 1-5 September
Assessment and significance of defects in structures	Cranfield	9-11 September
Intelligent systems for offshore and aeronautical industries	Cranfield	22-26 September
Calibration of flowmeters	Cranfield	23-24 September
Reliability of offshore structures, risers and pipelines	Cranfield	21-23 October
Flow in pipes - application of design data	Cranfield	4-5 November
Underwater engineering	Cranfield	24-28 November
Electromagnetic and ultrasonic flowmeters	Cranfield	2-4 December
Designing against fatigue	Cranfield	10-12 December
Marine mineral resources	London	To be arranged

For further details of individual courses or a copy of the brochure *Short courses in marine technology 1985-1986*, contact Mr J M Stuart, Marine Technology Centre, School of Industrial Science, Cranfield Institute of Technology, Cranfield, Bedford MK43 0AL. Telephone Bedford (0234) 750111 ext 2539, telex 825072 CITECH G.

Some new publications from SERC

Council's first corporate plan

The Science and Engineering Research Council corporate plan was published in December 1985. Copies are available from the Council Secretariat, SERC Central Office, Swindon, ext 2304.

Council's annual report

Report of the Science and Engineering Research Council for the year 1984-85 was published in November 1985. Copies are available from HM Stationery Office bookshops price £5.00 (ISSN 0261-7005; ISBN 0 901660 69 8).

Astronomy

Copies of the annual reports for the Astronomy I and Solar System Committees, both for the period 1 October 1983 to 30 September 1984, are available from the Committee Secretariats, SERC Central Office, Swindon, ext 2266 (Astronomy I) and ext 2366 (Solar System).

Mathematics

Mathematics Committee: review of activities 1983-84 issue: copies are available from the Committee Secretariat, SERC Central Office, Swindon, ext 2313.

Biological sciences

Reports by two panels, *Invertebrate neuroscience* and *Image interpretation,* as well as the *Biological Sciences Committee annual report 1984-85,* are available from the Committee Secretariat, SERC Central Office, Swindon, ext 2156.

Chemistry

Current grants in chemistry, 1 October 1985: copies are available from the Committee Secretariat, SERC Central Office, Swindon, ext 2126.

Civil engineering

Copies of the first issue of the *Civil engineering newsletter* are available from the Environment Committee Secretariat, SERC Central Office, Swindon, ext 2123.

Machines and power

Two publications are available from the Machines and Power Committee Secretariat (SERC Central Office, Swindon, ext 2116): the Committee's *Annual report 1984-85* and *Current Grants 1 August 1985.*

SERC enquiry points

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

ASTRONOMY, SPACE & RADIO DIVISION

Solar, ionospheric magnetospheric and middle atmosphere physics, lunar and planetary sciences, remote sensing aeronomy	Mr S D Ward ext 2317
Radio, millimetre, X-ray cosmic and heavy particle astronomy	Dr J H Price ext 2265
Optical, infrared and ultraviolet astronomy	Dr A G Game ext 2417
European Space Agency and remote sensing	Ms C A Iddon ext 2320 Miss C Armstrong ext 2367
PATT awards	Mrs R Brown ext 2198
Research grants	Mr R Guy ext 2359
Studentships and fellowships	Mrs S Lansdowne ext 2419
Computing	Mr J E Morgan ext 2383

ENGINEERING DIVISION

Medical engineering	Miss J Williams ext 2110
Materials	Dr S Milsom ext 2338
Environment	Ms C Marsden ext 2353
Civil Engineering	Mr N L Williams ext 2155
Process engineering	Dr R K Burdett ext 2476
Fluid mechanics and thermodynamics	Mr J W Reed ext 2478
Electrical engineering	Mr C P Whitlock ext 2350
Applied mechanics	Miss P A Rogers ext 2117
Joint ESRC-SERC; studentships & fellowships	Miss M Wilson ext 2153
Information dissemination	Mrs J Broughton ext 2238
Design	Mr A Spurway ext 2102

DIRECTORATES

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

NUCLEAR PHYSICS DIVISION

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

SCIENCE DIVISION

Biological sciences and pharmacy	Mr N Birch ext 2125
Computing	Mrs L Foster ext 2491
Mathematics	Mr F Hemmings ext 2312
Neutron facilities	Mr D M Schildt ext 2212
Physics	Mr J A Farrow ext 2261
Science-based archaeology	Dr P Sharma ext 2166
Laser facility	Mr P Burnell ext 2413
Chemistry and pharmacy	Dr J Wand ext 2263 Dr P Sharma ext 2166
Synchrotron radiation facility	Mr A Brown ext 2217
Cooperative Grants (Science)	Mr N Myer ext 2214

FINANCE

Account queries	Mr Ahmed Kamal ext 2434

RESEARCH GRANTS

Most enquiries should be addressed to the appropriate subject committee.

Terms and conditions/ supply of forms	ext 2405

STUDENTSHIPS: APPLICATIONS

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

STUDENTSHIPS: CURRENT

Ask switchboard for current studentships for your institution

FELLOWSHIPS

Postdoctoral (home, overseas and NATO), advanced and senior fellowships	ext 2172
Special Replacement Scheme	ext 2206
Royal Society/SERC Industrial	ext 2352
AAT	ext 2418
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, telephone Abingdon (0235) 21900, ext 5517.

SERC BULLETIN	ext 2120
ALL PRESS ENQUIRIES	exts 2257, 2256

The Council's twentieth anniversary

To mark the twentieth anniversary of the Science and Engineering Research Council, each of its four establishments held exhibitions and open days in September or October 1985. Local dignatories, industrialists, eminent scientists, the families of staff and several thousand secondary school children saw displays and models of the work of the Council, watched films and videos and were given guided tours round some of the major scientific facilities at each site. For many of the youngsters it was a day to remember and, it is hoped, will generate a lasting interest in science and technology.

A party from an Abingdon school visiting the Rutherford Appleton Laboratory learn of some of the achievements of IRAS, the Infrared Astronomical Satellite.

Members of the local press are given an introduction to the science of one of beamlines on Daresbury Laboratory's Synchrotron Radiation Source.

'Family night' at Daresbury.

Dr John McKay, Lord Provost of the City of Edinburgh, takes a look through a small telescope (at a terrestrial object because it was still daylight) at the Royal Observatory, Edinburgh, after the Lady Provost had opened the 'Popular Observatory'.

Some of the 1300 school children who visited the Royal Greenwich Observatory rest on the lawn outside the Observatory's Herstmonceux Castle, having seen telescopes, the Time Department, Satellite Laser Ranging and instrument development.